HABITAT CHARACTERISTICS AND POPULATION STRUCTURE OF THE FISHES OF THE UPPER VICTORIA NILE, UGANDA

BY

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DECLARATION

I hereby declare that this thesis is my original work and has not been submitted to any other university for examination.

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ABSTRACT

Globally, riverine fishes are important in supplementing lacustrine fish production. In Uganda, Upper Victoria Nile (UVN) is considered as a critical habitat to fish species reproduction, feeding, shelter and as source of food to the community. Yet information on population dynamics of resident fish species, biological integrity of riverine ecosystem, habitat quality is not known and catch rates of fish species in UVN are scanty. Further, information of the species *Mormyrus kannume* on growth patterns and exploitation is unknown. The main objective of the study was to determine habitat characteristics and population structure of the fishes of UVN. Specific objectives were: i) To characterise habitat quality in relation to physico-chemical parameters and fish community structure in UVN; ii) To determine the population dynamics of fish in UVN; iii) To determine trends in fishing effort and fish catches in UVN; and iv) To determine spatial and temporal abundance of bait fishery in UVN. The study covered twelve stations distributed between station 1 (ST1) to ST12. Out of twelve sampling stations, three were for catch assessment and effort data, while nine were for collection of fisheries, limnology, and ecosystem integrity datasets. Data were collected biannually from April 2014 to September 2019. Physico-chemical variables of water were measured using HacH HQ40d multi probe. Water samples were obtained in duplicate using 500mm borosilicate bottles prewashed with distilled water and nutrient analysis in laboratory was done following standard methods. Principle Component Analysis was used in water quality analysis. Nine-habitat metrics estimated habitat quality index (HQI). Fish biodiversity indices were estimated using occurrence and fish-based index of biotic integrity (FIBI) methods. Counts of exotic/indigenous and tolerant/intolerant species were recorded to generate species richness. Generated measurements were used to develop 12 metrics FIBI by summing up scores. Duplicate samples of fish were obtained using experimental gillnets of mesh sizes ranging from 25.4-203.2 mm. Fish Stock Assessment Tool (FISAT) and IBM SPSS Statistic Version 20 were used in data analysis of population structure. The study mainly focused on population structure, sexual maturity, food and feeding habits, growth parameters, growth performance indices, mortality rates, and yield per recruit.

Population dynamics characteristics of fish exhibited a lower size at sexual maturity (L_{50}) for males and females. For example, *L. niloticus, O. niloticus and M. kannume* (L_{50}) for males and females; 30.1 & 40.3 cm TL; 24.5 and 17.5 cm FL respectively. Fish community structure recorded5,202 fish specimens comprising 67 species belonging to 8 families. Species recorded, *Lates niloticus*13.82%, *M. kannume* 1.8%; *Oreochromis niloticus*0.54%,*Bagrus docmac* 0.41%*and* other including the haplochromines72%.Trophic guilds recorded omnivores (62.7%),carnivores (22.4%) and detrivores (14.9%). Mean HQI, (25.86-32.89), total fish catch and FIBI, (1.8-3.5) varied among stations that showed fair biodiversity that needed proper conservation measures of habitat type. The observed changes in annual changes were attributed to increased fishing effort along with gear changes from legal to illegal such as traps, nets below 5 inches based on Fishing rule (2010). The growth and morality parameters for commercial fishes such as *L.niloticus,O.niloticus,M. kannume, O. variabilis* recorded; length at infinity in centimetre total length and maximum age in years at 90.3, 8.1; 47.3,4.1 and 36.75;6.4 respectively. Total morality (Z) and exploitation rate (E) for same fish species were;Z=1.71 per year (yr-1), E=0.62; Z=2.80 yr-1, E=0.50; Z=1.74 yr-1, E=0.5 yr-1 respectively. That exhibited a decrease in population characteristics thus environmental stress. Annual fish production recorded> 70 percent low sized fishes that earned low market value. Estimated production showed high regeneration rates and often dynamic that needed regular monitoring to provide adequate information to inform management decisions. *M. kannume* recorded increase in annual catches and value of 40 tonnes (t) to 300 t in 2014 to 2019 respectively; though maturing at small sizes of male and females at 24.5 and 17.5 cm FL. That requires scientific attention on sustainability of the resources to avoid depletion and eventual collapse.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CPUE	Catch per unit of effort
CAS	Catch assessment survey
Cond	Conductivity
DO	Dissolved Oxygen
e	Exploitation rate
f	Fishing Mortality
FIBI	Fish-index of biotic integrity
FISAT	Fish Stock Assessment Tool
FS	Frame survey
FPC	Flood pulse concept
GDP	Gross domestic product
IUCN	International Union for Conservation of Nature
k	Growth constant
KMFRI	Kenya Marine Fresh Waters Research Institute
LVEMP	Lake Victoria Environmental Management Project
LVFO	Lake Victoria Fisheries Organisation
L_∞	Length at infinity
Lr	Recruitment length
NaFIRRI	National Fisheries Resources Research Institute
NH4-N	Ammonia nitrogen
NO2-N	Nitrite nitrogen
NO3-N	Nitrate nitrogen (Soluble reactive nitrogen)
HQI	Habitat quality index

M	Natural Mortality
^{o}C	Degrees Celsius
QHEI	Qualitative habitat Evaluation index
PO4-P	Ortho Phosphate (Soluble reactive phosphate)
PSU	Primary sampling unit
RCC	River continuum concept
RST	Riverine surface Temperature
SD	Secchi depth
SDC	Serial Discontinuity Concept
SDG	Sustainable development goals
SIO2-S	Silicates
SPSS	Statistical Package for the Social Sciences
SOPs	Standard Operating Procedures
SSU	Secondary sampling unit
T	Mean temperature
TD	Total depth
TN	Total nitrogen
TP	Total Phosphorous
TSS	Total suspended solids
UVN	Upper Victoria Nile
VG	Vessel gear
VPA	Virtual Population analysis
Y/R	Yield per recruit
z	Total Mortality

WORKING DEFINITIONS OF TERMS

Catch assessment: - Catch Assessment Survey. The actual counts and weights of the fishes caught by the local fishers at the major landing site

Fish diversity: -Comprises of species richness (number of species in a defined area), species abundance (relative number of species) and phylogenetic diversity (relationships between different groups of species)

FIBI: -Fish index of biotic integrity (FIBI), integrate various fish knowledge on assemblage, trophic level, origin, and function into a single ecologically based index. The index can give a clear correlation with land use and physical habitat variables.

Habitat characteristic:-The habitat is an area habited by either terrestrial or aquatic organisms. It comprises the earth's surface structure and biological features that influence the niche's structure and energy input.

HQI: - Habitat quality index (HQI) models used to evaluate habitat quality for wildlife at a local scale.

Flood Pulse Concept (FPC):- Explains how flood is an important entity in promoting Ecosystem diversity. Floods create different site conditions that trigger the growth of preferred vegetation.

Frame survey: -Study that undertakes a census of fish landing facilities, Total number of fishers, boat types, fishing gears, propulsion, primary schools.

Native: -The quality of belonging to or being connected with a certain place or region by birth or origin

Pristine: -A state or quality of being excessively prime or proper.

QHEI -Quantitative habitat assessment requires measurement of Stream variables such as channel sinuosity, speed of the river, buffer coverage, number of riffles vegetation cover, the width of through river.

River Continuum Concept (RCC): - describes how biodiversity change downstream.

The change is due to the variation of physical environmental conditions.

Serial Discontinuity Concept (SDC): - highlights the usefulness of nutrients toward promoting diversity along rivers. Nutrient enrichment promotes primary productivity in aquatic ecosystems; hence assemblage of aquatic dependent fauna

Species richness: - Fish richness refers to the number of different fish species available in an aquatic habitat.

Simpson index: -Measures the probability that two individuals randomly selected from a sample will belong to the same species. The index stresses on the evenness component and on dominant type.

Shannon-Wiener index: - Emphasizes on the richness component and rare types of individuals.

Resilience: -The physical property of a material that can resume its shape after being stretched or deformed; elasticity

Annual Sustainable Yield: - Annual Sustainable Yield (ASY) is defined as biomass harvested from a fish population each year without resulting in a decline. ASY is dynamic and is adjusted based on population levels and performance of the previous year's fisheries.

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Rivers and streams are major features of most types of landscape although their total areas are only about one thousand of the land surfaces (Allan and Castillo, 2007; Naiman and Bilby, 1998). These rivers and streams drain a large amount of land surface water into seas and lakes. Touching all parts of the natural environment and nearly all aspects of human life culture, rivers act as integrators and centres of organization within the landscape. The roles of rivers in providing natural resources, such as fish and clean water, has been known, as are their roles in providing transportation, energy, diffusion of wastes, and recreation (Allan and Castillo, 2007; Naiman and Bilby, 1998). Hence the Upper Victoria Nile as one of the rivers in the ecosystems in the world that plays the same role as others in the ecosystem.

The Upper Victoria Nile is part of the Nile system (Figures 1.1 and 3-1) the longest river in the world (ca 6,800 km) and its basin ($2.9x10^6$ km^2), including its various “source” lakes (Dumont, 2010; Nile Basin, 2012). River as it leaves the lake near Jinja in the north, crossing the Owen falls (ca 30m high), flowing rapidly for the next 70km, to slow upon reaching the dendrites swam-lake Kyoga is called the Victoria Nile then from Lake Albert is the Albert Nile (Dumont, 2010; Nile Basin, 2012) (Figures 1-1 and 3-1).The Upper Victoria Nile is one of the ecosystems with unique features such as rapids and falls that have been used as tourism sites such the Bujagali falls, Kalagala falls and fast mowing waters with aquatic creatures such as the crocodiles that may not be found in some rivers. It is one of the ecosystems that is still inhabiting the *Oreochromis variabilis* fish species in the East African region a species that considered endangered (Twongo *et al.*, 2006). The haplochromine species such as

Neochromissimotes is found is some of the habitats in the UVN that endangered species (Atkins, 2001).

Studies reported that dam construction on the Upper Nile had an impact on the ecology, water quality, fish stocks, plankton ecology, and insect emergencies downstream (Talling, 2010). The Upper Victoria Nile region has various developments such as the old Owen falls, a second dam at Bujagali falls and a third at Isimba falls the Isimba dam. It also has industries such as Nile Breweries, Paper-manufacturing factory (PAPCO), Steel rolling mills and Nile Garments factory constructed along the upper Nile stretch. The developments mentioned above, unsustainable agricultural practices such as tilling of the land up to the riverbanks, use of fertilizers and pesticides and deforestation contributed to the catchment's degradation. In the UVN river banks the most dominate crops are sugar cane growing and vegetables that are sold to communities in the Jinja city. These activities result in poor water quality that affects the general ecology of the riverine ecosystem, including the fisheries. Since the establishment of the East African Freshwater Fisheries Research Organisation in 1947, research focused on the ecology and fisheries of lakes and less on rivers in the region. However, previous studies critically focused on fish taxonomy of keystone species. These studies established fish distribution patterns and trophic ecology relationships at the interphase between Lake Victoria and the Nile between the Napoleon Gulf and the Owen falls dam. During the study, 14 fish species identified were *Mormyrus kannume, Lates niloticus* and the haplochromines fishes being the most dominant. The studies further revealed that fish species diversity was high in shallow inshore areas of the interphase due to increased heterogeneity provided by the ecotone macrophytes. Species such as *Bagrus docmac* and *Barbus altinialis* were not observed at the interphase but occurred in the riverine habitat (Nkalubo, 2001). Other studies indicated variation in distribution and biological characteristics of fish in the Upper Nile region. Twenty-four (24) species that were grouped into ten families were identified from gillnet catches. The most abundant species were *Lates niloticus*, *Mormyrus kannume*, *Synodontis victoriae*, *Synodontis afrofisherie* and *Coptodon zilli* (Oyango, 2004). These two studies were undertaken before the constructions of the Bujagali and the new second Kiira dam. Further, studies were carried out on the influence of Bujagali dam on the spatial and temporal fish assemblage in the Upper Nile (Tazibirwa, 2016). The monitoring reports of Bujagali hydropower dam limited (BELL), (Burnside, 2006) and those done by (Nkalubo,2001), (Onyango,2004) and (Tazibirwa, 2016), did not address the growth, mortality, annual estimates, recruitment, size at first maturity of the important fishes of the UVN and bait fishery that needed a detailed study, addressed by this thesis.

The Upper Victoria Nile and the adjourning lakes are important sources of large amounts of hydro power such as the dams and fossil hydrocarbon deposits. Such developments may contribute to river pollution, which still a local phenomenon, except in Lake Victoria, which suffers from eutrophication with substantial industrial development (Ogutu, 2008; Dumont, 2010).

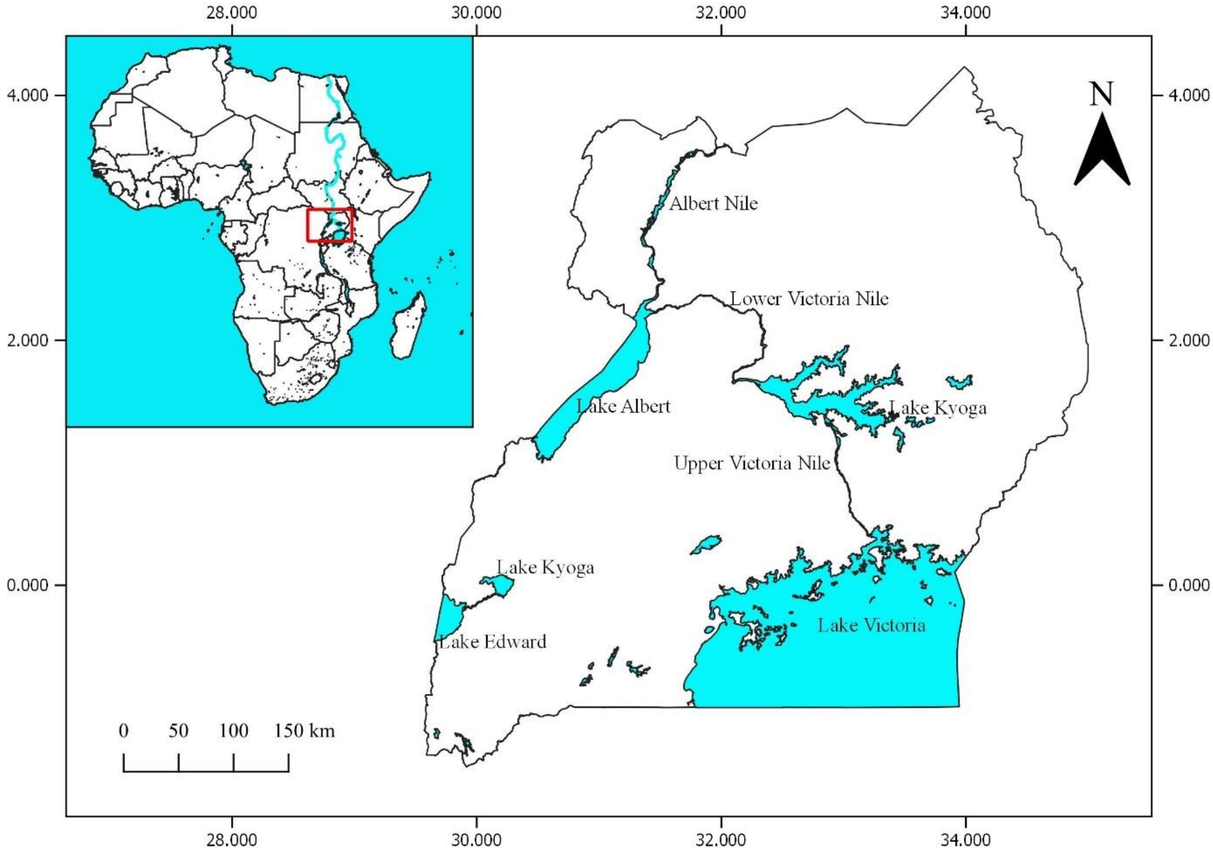

Figure 1-1Map of Upper Victoria Nile part of the River Nile (Inset: map of Africa).

In the East African region (Kenya, Uganda, and Tanzania), several rivers flow into Lake Victoria, and it is only the River Nile that flows out of the lake (Frank *et al.,* 2012). These rivers play a role in the fisheries of Lake Victoria and the rivers themselves. These sites act as spawning grounds for most fishes, such as the catfishes that migrate upstream and later back to the lake for feeding (Kibara, 1981; Balirwa *et al.,* 2003; Booth***et al.,*** 2004; Nkalubo *et al.,*2018). However, besides other development along the rivers, the community living in the riparian zones have continued to transform the (UVN) ecosystem through agricultural activities, deforestation, and dam constructions, thus negatively affecting the river habitat and the fisheries resources (Burnside, 2006; Tazibirwa, 2016).

1.2 The Fisheries and Environment of the Upper Victoria Nile

The (UVN) is a resource to the riparian people for income and food. It may be considered critical to fish species for reproduction, feeding, and shelter. The critical habitats include rocky areas, sheltered bays, shallow areas, wetlands, and inflow streams into the river. It is used off-stream (withdrawn e.g., for agriculture or domestic use), in-stream (e.g., hydropower, fisheries, environment), or on-stream (e.g., transport, tourism). The fishery that is a major resource from the ecosystem has been affected by changes in the watershed (Burnside, 2006; Dumont, 2010; NaFIRRI, 2018). A change in the ecosystem has been due to the drivers such as anthropogenic activities and the hydropower developments along the river. The parameters that have affected the fisheries resource are physical and chemical variations in the ecosystem. Physico-chemical variables such as water temperature, turbidity, pH, conductivity, nutrient levels, depth, altitude substrate and other aquatic variables such as plankton community, and influence fish composition (Busulwa *et al.*, 1998; Burnside, 2006; Albinus *et al.*, 2008; Sitoki *et al.*,2010;Li *et al.*, 2012).Studies from lakes and rivers indicate that activities such as land use modification greatly accelerate changes in aquatic ecosystems. The recent expansion and accelerating rate of deforestation have caused widespread concern, particularly in the tropics, where the impacts of deforestation and forest degradation on aquatic systems remain largely unknown (Chapman and Chapman, 2003).

Internationally, the existence of regions with limited human impact is sporadic. Most aquatic ecosystems in the world have been disturbed or altered in some way and thus have subsequently lost their pristine characteristics (Chapman and Chapman, 2003; Meybeck, 2003; Rockstroom *et al.*, 2014).The (UVN)is one of the systems that has been facing such problems that need attention for management purposes.

The fish species composition, distribution, and relative abundance in Lake Victoria have been assessed using both experimental bottom trawl and gillnet surveys (Okaronon, 1994; Nkalubo *et al.,* 2018). Studies showed that the size structure of a fish population reveals many ecological and life-history traits, such as the ecosystem health or stock conditions, even a basic description and length distribution having a great value for reference as well as for comparison (Okaronon, 1994;Ranjan *et al.*, 2005;Lemma *et al.*, 2015).Certain factors have affected the fisheries of Lake Victoria have led to riverine fisheries, more so the Nile stock level. Besides that, a new regime of the bait fishery on the UVN such as the small basket traps laid in the rocky areas of the river. The main target fish species exploited by the fishers is the *Mormyrus kannume*, yet information on the growth patterns and exploitation is unknown in addition to the stock abundances.

The catchment of Lake Victoria constitutes the most important lacustrine basin in terms of fisheries in East Africa. More than 180 fish species have declined in the Victoria basin and its riverine ecosystems (Fish Base team RMCA and Geelhand, 2016; Orina, 2018). The loss of fish species has been due to anthropogenic activities in the lakes' catchment (Hardin, 1995;Bassa, 2011; Ogello *et al.,* 2013; Orina, 2018). Lake Victoria, where the UVN comes from,receives its water from rivers Nzoia (12,842 km^2), Kuja-Migori (6,600 km^2), Nyando (3,652 km^2), Sondu-Miriu (3508 km^2), Yala (3357 km^2), Kagera (400km^2), Katonga and Sio (1437 km^2) then flow out through the UVN at the source of the Nile, thus the Rippon falls. Studies on the characteristics of lacustrine riverine fisheries were done on Rivers Sondu-Miriu (3470 km^2), Nzoia (12,900km^2), Mara (14430 km^2) (Raburu and Masese, 2010; Mwangi *et al.*, 2012). In these rivers habitat characteristics and fish index of biotic integrity were studied yet not addressed the UVN basin. The habitat for these fishes in the riverine ecosystem is a significant key in the fishery's sustainability and production. This study addressed the habitat quality (HQI) and fish index of biotic integrity in relation to the water parameters to have a complete picture of the UVN ecosystem. It mainly focused on the population structure and habitat characteristics of the fishes of the UVN,Uganda.It also addressed the population dynamics, annual trends, recruitment, growth of the fishery catches of the UVN and how the bait fishery is exploited, growth patterns, annual and value trends mainly the *Mormyrus kannume* as the primary target fish. This information was vital for fisheries resources conservation.

1.3 Statement of the problem

The UVN is one of the ecosystems that is habited by the fisher community along its shores who are highly dependent on it. It is a source of tourism, especially the Bujagali and Kalagala falls thus a high source of revenue to the country and a contributor to the Gross Domestic Product (GDP). These anthropogenic activities have affected the habitat’s quality and fish community structure of the fisheries of the UVN that remains a subject to be addressed. The fishery of the Upper Victoria Nile is subjected to heavy fishing pressure such that the stocks' stability is questionable. There is limited knowledge in the development of predictive sustainable fishery management regimes. This limited information has also hindered estimation of annual and long-term variations in recruitment patterns and the limited knowledge of how these fishes respond to the strong selection pressure induced by fishing. There is limited information on the recruitment, growth, and population parameters in this dynamic fishery. In addition, there is limited information on population dynamics of the Upper Victoria Nile fishes.

Further, the impacts of the bait fishery on fish stocks have not been assessed in past studies. In the UVN the main bait fishery is the *M. kannume*used by fishers that target for the Nile perch harvest in Lake Victoria. Despite the decline attributed to overfishing due to the species high demand (Balirwa 2007; Balirwa 2008; Ogutu-Ohwayo *et al,* 2013; Yongo *et al.,* 2018), the new fishing regimes that included the use of inefficient gears have led to the stock decline of the native fishery from the UVN. The decline of these species in the lakes has led the riparian people to exploit the riverine system, including the UVN to meet the demand and supply.

Therefore, this study addressed the growth and life history traits of the UVN's main commercial fish species. Thestudy involved determining the habitat and water quality, recruitment, sizeselection predation, predicting the future of the fishery, and value of the current fishing regulations on the slot size of the commercially important fishes such as the *Lates niloticus*and size at first maturity of *Oreochromis niloticus*,*Oreochromis variabilis* and *Mormyrus kannume*.

This study, therefore, addressed the following questions on the Upper Victoria Nile ecosystem: -

- How has the habitat quality (HQI) in relation to the physico-chemical characters affected the fishery of the UVN?
- Is there a variation in the population dynamics characteristics of fishes of the UVN?
- What are the trends in fishing effort and fish catches of the UVN?
- How has bait fishery affected the *Mormyrus kannume* species in the UVN ecosystem?

In order to address these questions, there was a need to have an integrated approach to fisheries.

1.3.1 Main objective

The main objective of the study was to determine habitat characteristics and population structure of the fishes of Upper Victoria Nile (UVN) in the Bujagali area in Uganda.

The specific objectives

i) To characterise habitat quality in relation to physico-chemical parameters and fish community structure in the UVN.

ii) To determine the population dynamics of fish in the UVN.

iii) To determine the trends in fishing effort and fish catches in the UVN.

iv) To determine the spatial and temporal abundance of the bait fishery of the fishes in the UVN, focusing on *Mormyrus kannume.*

1.4 Hypothesis

H_{o1}: There are no significant differences in habitat quality indices in relation to physico-chemical parameters at the different sampling sites of the UVN.

H_{o2}: There are no significant differences in the population dynamics of fishes of UVN.

H_{o3}: There are no significant differences in effort and fish catches at the different sampling sites at the Upper Victoria Nile.

$H_{o4:}$There are no significant differences in the spatial and temporal distribution patterns, characteristics, dynamics and impacts of the bait fishery of fish at the different sampling sites of the UVN.

1.5 Justification of the Study

The demand for fish has increased with an increase in the population. This increased demand has led to a decline of the fisheries in the ecosystems, including the riverine (Ogutu-Ohwayo,*et.al.,*1998; Nkalubo, 2012; Mkumbo *et al.,* 2007; Balirwa *et al.,* 2003).With the increase in the population, fish export markets both internationally and locally have subjected the UVN fishery to intensive fishing. Fish provides jobs at the local markets and income. Further, the fishery plays a role in the health of the populations along the UVN. Culturally there is a belief that children fed on haplochromines are always cured of measles. So, the local communities use this fish species to feed their children, especially when attacked with such diseases. The increased exploitation of the Nile perch had led to a new regime bait fishery of *M. kannume* in the UVN ecosystem. Besides crop farming in this region, fisheries is a big business for the community, thus play a role in poverty eradication, fulfilling the sustainable development goals (SDGs).

In Uganda, the population is increasing at 3.4% annually (Balirwa, 2007; World Bank, 2019), and part of this population of these people depend on the fisheries resources from the Victoria basin systems. However, investors have constructed factories and industries close the shores the lake and riverine ecosystem such as the UVN. These industries act as a point source for effluents into the UVN, thus polluting the ecosystem which affect the health of the human population, the fisheries, and the habitat types. The over-dependence on the fisheries raise concern and creates uncertainty about the sustainability of the fishes' stocks. There is a critical need to effectively manage and monitor the fishery populations and their habitats to promote sustainable fishery and biodiversity conservation. This study contributes to the above efforts by providing knowledge on habitat characteristics, population structure and catches of the most commercial fish species such as the Nile perch, Nile tilapia, *M. kannume* and *O. variabilis* and bait exploitations from the UVN.

1.6 The Assumptions, Limitations of Research

The study covered areas in Kiira dam up to the lower parts of Bujagali dam in areas of Buyala that is 5 km from the dam, constructed area of Bujagali. The study used data from **frame** surveys, catch assessment surveys, **e**xperimental gillnets, water quality and habitat to address the objectives of the study.

The assumptions were: (i) The study undertaken should be able to address the hypotheses and tested in a cause effect manner. (ii) The objectives of the study were expected to help the scientific researcher to predict, explain, and understand phenomenon.

The limitations of the study collecting data from only twenty boats from each landing sites in accordance to the standard operating procedure (LVFO, 2005b) more especially when such sites have less that the recommend fishing canoes. The second limitations were the weather changes during the samplings such as rains and rough weather.

1.7Ethical Considerations

During data collection, the ethical considerations were - i) not to allow the fish to suffer or cause pain during the experiment hence put on ice to avoid causing harm. In addition, the gillnet experiments used the standard operating procedure of gillnetting of LVFO (2005). ii) Catch assessment and frame survey experiments data collection used the standard operating procedures of LVFO, (2005a and b). iii) During data collection, there was no need to have a permit because the National Fisheries Resources Research Institute (NaFIRRI) is mandated to carry out fisheries research both locally and internationally. Though the researcher was working with the organization, permission was granted to him by the administration to undertake research on the UVN ecosystem. iv) For water, sample collection and analysis followed the Standard Operating Procedure by LVFO (2005) and APHA(2005).

CHAPTER TWO

LITERATURE REVIEW

2.1 Riverine Ecosystem: Their Structure and Function

Rivers are among the ecosystems that are fascinating and complex. The riverine ecosystem touches all parts of the natural environment, nearly having inclusion of human culture and act as integrators and centres of organization in the landscape (Naiman and Bibly, 1998; Allan and Castillo, 2007;Diego*et al.*, 2017). Such ecosystems provide natural resources such as fisheries and clean water provides energy, transportation, diffusion of wastes (pollution diffusion) and recreation like sport fishing. However, what is not well known is how such ecosystems are structured and how they function as ecological systems. People living along the riparian shores of the rivers have exploited the natural benefits provided by the running waters without understanding how these ecosystems maintain their vitality (Naiman and Bibly, 1998; Diego *et al.*, 2017). The increasing human population has led to increased exploitation of the fisheries resources of the riverine systems. Therefore, ecological understanding of rivers' structure and dynamics is essential for formulating sound management and policy decisions.

In Uganda, the Upper Victoria Nile is one of the ecosystems that has been inhabited with a high human population that depend on the ecosystems. The Upper Victoria Nile starts from the source of the Nile at Owenfalls dam. It is inhabited by various types of fishes and acts as a harbour for some species that might have dwindled from Lake Victoria. The ecosystem has undergone modifications like dam constructions besides intensive fishing and anthropogenic activities that might have affected the ecosystem in terms of water quality, the fisheries in terms of food and feeding, recruitment and growth performance ((Naiman and Bibly, 1998; Ogello *et al.*,2013).

There is a scanty of information on the fisheries and limnology of the Upper Victoria Nile. Most of the literature on these topics are stale and date back to the 1950's and early 1960 and focused mainly on fish taxonomy and ecology. Dumont (2010) suggested that the contribution of the riverine fishery of the Nile to the fish catches in the region is minimal. This observation (Dumont*op cit*) may not be accurate because of insufficient information on fish production of the river. Knowledge base on African riverine fisheries is highly localized and based on short-term studies conducted before the 1990s (Atkins, 2001; Burnside, 2006; Dumont, 2010; Witte *et al.*, (2010).Despite the limited information on the UVN ecosystem, there is a substantial body of research undertaken on the fisheries of the Lower Nile in Lakes Borullas and Manzara in the Nile Delta in Egypt (Witte *et al.*, 2010).Recent studies have been conducted by the National Fisheries Resources Institute, Uganda for Total E&P Uganda on any likely future impacts of oil mining on fish communities of Lower Victoria Nile, Ramsar site area of Murchison falls National Park (MFNP) (Mbabazi*et al.*,2014).

Studies reported that dam construction on the Upper Nile had an impact on the ecology, water quality, fish stocks, plankton ecology, and insect emergencies downstream (Talling,2010).Since the establishment of the East African Freshwater Fisheries Research Organisation in 1947, research focused on the ecology and fisheries of lakes and less on rivers in the region. However, previous studies critically focused on fish taxonomy of keystone species. These studies established fish distribution patterns and trophic ecology relationships at the interphase between Lake Victoria and the Nile between the Napoleon Gulf and the Owen falls dam. During the study, 14 fish species identified were *Mormyrus kannume, Lates niloticus* and the haplochromines fishes being the most dominant. The studies further revealed that fish species diversity was high in shallow inshore areas of the interphase due to increased heterogeneity provided by the ecotone macrophytes. Species such as *Bagrus docmac* and

Barbus altinialis were not observed at the interphase but occurred in the riverine habitat(Nkalubo, 2001).Other studies indicated variation in distribution and biological characteristics of fish in the Upper Nile region. Twenty- four (24) species that were grouped into ten families were identified from gillnet catches. The most abundant species were; *Lates niloticus*, *Mormyrus kannume*, *Synodontis victoriae*, *Synodontisafrofisherie* and *Coptodon zilli*(Onyango, 2004). These two studies were undertaken before the constructions of the Bujagali and the new second Kiira dam. Further, studies were carried out on the influence of Bujagali dam on the spatial and temporal fish assemblage in the Upper Nile(Tazibirwa, 2016).The monitoring reports of Bujagali hydropower dam limited (BELL) reported twice a year (Burnside, 2006)did not address the growth, mortality, annual estimates, recruitment, and size at first maturity of the important fishes of the UVN that needed a detailed study.

2.2 Models of Riverine Ecosystem functioning

Generally, natural processes and anthropogenic activities influence the integrity of the riverine ecosystem. Several models have been developed to explain the fundamental natural factors that shape the lotic ecosystem for example that of the Upper Victoria Nile and other rivers in the world. Some of these models like the River Continuum concept (RCC) (Vannote *et al.*, 1980), Discontinuity (Ward and Stanford, 1983) and Flood Pulse Concepts (Junk and Sparks, 1989) address the flow regimes. The River Continuum Concept (RCC) describe how biodiversity changes downstream. The changes are attributed to the variation of physical environmental conditions. As the water width, depth, temperature, and complexity increased downstream, the relationship between production and consumption change (Vannote *et al.*, 1980;Naiman and Bibly, 1998).

The second model, Serial Discontinuity Concept (SDC), indicate the usefulness of nutrients toward promoting diversity along rivers (Ward and Stanford, 1983, Orina, 2018). Nutrient enrichment promotes primary productivity in aquatic ecosystems hence the assemblage of aquatic dependent fauna. Consequently, it could lead to a decrease in the biomass of important native autotrophs. Biomass reduction is due to competition and an increase number of fauna communities (Ward and Stanford, 1983;Naiman and Bilby, 1998).

The third model was the Flood Pulse Concept (FPC) that explain how floods are important entity in promoting ecosystem diversity. Floods created different site conditions that trigger the growth of preferred vegetation and created spawning habitats of aquatic fauna such as fish and replenished dry water bodies. Despite these advantages, floods promote the introduction of new species in an area. This introduction, in turn, influence biodiversity in particular habitats in the ecosystem (Junk and Sparks, 1989).

Besides the natural factors described above, human activities cause a more significant change to riverine ecosystem integrity (Deng *et al.,* 2017). Some of the activities include industrial developments that lead to a discharge of industrial effluents, deforestation, use of fertilizers and pesticides near ashore. These developments lead to nutrient enrichment, thus surpasses natural fixation in the river. Therefore, human activities are likely to greatly impact resources, ecological and integrity of the riverine ecosystem, thus its biodiversity and the fisheries(Vitousek *et al.,* 1997; Niemi and McDonald, 2004;Orina *et al.,* 2018).Vannote *et al.* 1980 formulated the hypothesis that structural and functional attributes of communities distributed along the river gradients conform to the most probable position. The hypothesis tends to underlay a principle of uniformity in the riverine systems in terms of fauna as the river tend to flow from the upper to the lower zone system in terms of biotic organism from the shredders, grazers, predators, collectors, and microbes to zooplanktons and finally the fish (Vannote *et al.* 1980). The stream size and ecosystem structure and function of the Upper Victoria Nile were affected by many developments, thus deviating from the Vannote principle, the use of habitat quality index and fish index of biotic integrity is best fit to understand the fish community structure in relation to habitat type and physico-chemical characteristics. The riverine fishes such as, The *Mormyrus kannume,* the *Labeo* species, the *Clarias,Bagrus docmac,* Barbus species spawn in the riverine habitats and then migrate to the lake ecosystems for feeding and growth. This migration pattern occurs during the two rainy seasons in a year (Kudhogania and Cordon, 1971a&b; Ogutu-Ohwayo, 1984; Kibara, 1981; Coenen, 1991; Rutaisire and Booth, 2004; Nkalubo *et al.,* 2018). Therefore, the riverine environment acts as refugia for these fishes and helps the lake continue having such species in the ecosystem. The economic developments on and along the river course of the Upper Victoria Nile in addition to intensive fishing may have led to the decline in the fisheries resources and its growth patterns.

2.2 Bio-Ecological Indicators/Monitors

Scientifically, four principles can be used in assessing ecosystem integrity: nativeness, pristineness, diversity, and resilience. The nativeness refers to the degree to which biota is indigenous. If the abundance of native species is high, then the ecological status is also high (Clayton and Edwards, 2006; Allan and Castillo, 2007). This concept is supported by the principle of pristineness, which shows when and where the habitat is undisturbed. It explains that if the habitat is in its natural state, then it provides adequate resources sustainably. However, it will always rely more on the structural functionality and physico-chemical parameters than the use of biota (Naiman and Bibly1998)

The principle of diversity refers to the state of having different components that coexist. The components can be habitat, ecosystem, flora, or fauna within a community. Diversity is attained when an ecosystem is unimpaired or minimally disturbed. The ecosystem resilience principle explains the minimal disturbance of the ecosystem. This principle confirms that an ecosystem is never dead because if the discharge of all pollutants stopped into a river or a lake, then the polluted ecosystem will automatically revive itself(Orina *et al.,* 2018). The principles mentioned above complement each other during the assessment of riverine integrity.

2.3 Riverine Ecosystem Integrity

Ecosystem integrity, is referred to the completeness and functionality of an ecosystem. More intact ecosystems support higher biodiversity and reduce extinction risk; conversely, more degraded ecosystems support lower biodiversity and have higher extinction risk (Rohwer and Marris,2021).

Rivers provide goods and services for use mainly by humankind and other forms of life such as wild animals and birds. The goods and services are quantified to estimate the extent of deviation from normality. The latter arises from overexploitation of rivers and their catchment. Further, exploitation degrades the quality of the riverine ecosystem and may result in a point where the latter may stop to function and no longer provide the goods and services. In compromised ecosystems, health becomes very expensive and or sometimes impossible to revert to its original status. To avoid such scenarios, there is a need for regular assessment of the ecological integrity of the rivers (NaFIRRI, 2018; Atkins, 2001).

Various methods are employed to assess the ecological integrity of riverine ecosystems (Atkins, 2001; Orina *et al.,* 2018). Traditionally, assessment relied on the physical and chemical characteristics of water. Later, the use of living organisms has proved to be effective due to their ability to spell out the environmental conditions. The organisms tend to migrate, hibernate, or aestivate on exposure to unfavourable conditions. Prolonged exposure to adverse conditions could lead to death (Naiman and Bibly, 1998; Atkins, 2001). In most cases, the three methods usually applied in riverine ecosystem assessment are the physical and chemical characteristics of water, habitat quality, and the aquatic organism, especially the fish (Naiman and Bibly, 1998; Orina *et al*., 2018).

2.5 The Limnology of Riverine Ecosystems

2.5.1 Physico-Chemical Parameters

Water is the major resource in the river ecosystem, and thus its assessment can provide information on the quality of the environment. Physical examination involves assessment of water temperature, light, turbidity, and total dissolved solids among others. Temperature is one of the critical factors that influence the occurrence of aquatic living organisms. Water temperature in rivers rises due to direct exposure to sunlight, thermal pollution from industries or a high concentration of suspended solids that absorb solar energy. The increase in temperature can lead to changes in the distribution and abundance of aquatic living organisms. Light is another important factor that is the main driving source of energy in primary production. The amount of light reaching the riverine ecosystem; has always been affected by the riparian vegetation's shedding effect. Similarly, its penetration in the water column depends on turbidity, which is affected by total suspended solids and dissolved organic and inorganic matter arising from the catchments. Turbidity affects producers and consumers' distribution and abundance in a riverine ecosystem (Wetzel and Lakens, 1990;Wetzel and Lakens, 2001; Atkins, 2001; NaFIRRI, 2018).

There are also the Physico-Chemical variables used to assess water such as dissolved oxygen concentration (DO), nutrient concentration and pH among others. These parameters are important to aquatic organisms' survival since they determine their distribution**,** abundance, and well-being. The concentration of oxygen in the water column introduced by the autotrophs during photosynthesis or infusion from the atmosphere can decrease due to thermal pollution, decomposition, or increased respiration rate in rivers. The DO concentration in rivers affects the distribution and abundance of living organisms since it is an important requirement in the respiration of organisms. Dissolved oxygen (DO) is the most important chemical parameter in fish production, especially in freshwater ecosystems (Butler and Burrows, 2007). Low DO levels are responsible for more fish kills, either directly or indirectly than all other problems combined. Like humans, fish require oxygen for respiration and is, therefore, a limiting factor to most aquatic organisms (Franklin, 2014). Consequently, the DO concentration of water is a key control of habitat quality and a critical measure of aquatic environmental health (Franklin, 2014). The amount of oxygen consumed by the fish is a function of its size, feeding rate, activity level, and temperature. Small fish consume more oxygen compared to large fish because of their higher metabolic rate. The amount of oxygen dissolved in water decreases at higher temperatures, altitudes, and salinities. To obtain good growth, fish require optimum levels of dissolved oxygen at saturation or at least 4.0mg/l. DO levels greater than 15mg/l can stress the fish, and levels less than 2mg/l will result in death (Timmons *et al.*, 2001). The recommended minimum DO requirements are as follows: Cold-water fish - 6 mg/l representing 70% saturation, Tropical freshwater fish- 5 mg/l representing 80% saturation, and Tropical marine fish- 5 mg/l representing 75% saturation. These values are the minimum requirements for healthy growth, tissue repair, and reproduction (Svobodova *et al.*, 1993). Most fish species will tolerate a drop below these minimum values for a short period, and probably the cold-water species are likely to tolerate a lower level than tropical fish(Epps, 2011).

PH, as a chemical parameter, influences the occurrence, distribution, and abundance of different living organisms in rivers. Water pH is influenced by acid rain, agricultural runoff, industrial discharge, and fossil fuel emission (Muyodi and Hecky 2005; Allan and Castillo, 2007). Low water pH often results in physical damage to living organisms and increases the solubility of minerals. The water quality in rivers is a key concern in the world since it is used for drinking, domestic purposes, irrigation, and support of aquatic life. Its assessment is critical for ensuring that good water quality is available for use. For Lake Victoria, the situation is contrary since available literature indicates that its water quality has been changing due to anthropogenic activities since the 1920s (Muyodi and Hecky 2005; Olokotum, 2017). These changes have led to the occurrence of regular dense algal blooms and the proliferation of the water hyacinth and other aquatic weeds in the lake, thus rendering the water unsuitable for use.

Temperature affects the activity, behaviour, feeding, growth, and reproduction of all fishes in the aquatic ecosystem. Metabolic rates in fish double for each 7.8 ºC rise in temperature. Fish are generally categorized into warm water ranging from 23.8 – 32.2 ºC, cool water ranging from 18.3 – 23.8 ºC and cold-water species ranging 12.7- 18.3 ºC based on optimal growth temperatures (Boyd, 1979; Olukotum, 2017). Tilapia species are examples of warm water species. Their temperature range for growth is between 20-32ºC. A temperature of 23–32ºC is considered optimum for Catfish and Tilapia fish species. Temperature also determines the amount of dissolved gases such as oxygen, carbon dioxide, and nitrogen in the water. Temperature plays a significant role in the physical process called thermal stratification (Boyd, 1979; Olokotum, 2017), which in turn influences nutrient distribution in aquatic systems.

Electrical Conductivity (EEC) is a measure of the ability of water to pass an electrical current. Water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge). Its units are µS/cm (micro-Siemens/cm) (APHA, 1995). Conductivity is highly affected by temperature and shows a significant correlation with pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids and chemical oxygen demand, chloride, and iron concentration of water (APHA, 1995). Notably, the warmer the water, the higher the conductivity. Electro conductivity (EC) is measured on a scale from 0 to 50,000 μS/cm. Freshwater is usually between 0 and 1,500 μS/cm and typical seawater have a conductivity value of about 50,000 μS/cm (APHA, 1995). Studies of inland freshwaters indicate that lakes and streams supporting well mixed fisheries range between 150 and 800 µs/cm to support diverse aquatic life (APHA, 1995).

Total suspended solids (TSS) are large particles, which usually settle out of standing water throughout time. These solids, in streams and lakes, are in two forms, suspended, and dissolved solids. Suspended solids include silt, stirred up bottom sediment, decaying plant matter, or sewage treatment effluent. Suspended solids will not pass through a filter, whereas dissolved solids will go through a filter. High levels of suspended solids are a pervasive problem in streams, rivers, and lakes throughout the world(Augspurger *et al.,* 2003;Galbraith and Vaughn, 2009). Elevated suspended solids negatively influence ecosystem processes and aquatic biota. Decreasing light penetration, caused by increased suspended solids, can shift algae and aquatic plant assemblages and lead to changes in species interactions. Additionally, suspended sediments disrupt fish spawning by reducing contact between sperm and egg or sedimentation, leading to changes in substrate conditions. Anoxic conditions created by sedimentation alter biogeochemical processes and can foster increases in interstitial un-ionized ammonia, which can be toxic to benthic dwelling organisms (Galbraith and Vaughn, 2009; Augspurger*et al.,* 2003). Suspended solids are usually associated with plankton, fish wastes, uneaten fish feeds, or clay particles suspended in the water. Clay particles and other soil particulate matter are in suspension because of the negative electrical charges.Most clay turbidity problems result from exposed soil on the land around the lake, exposed watershed, or feeding of bottom-dwelling species such as Catfish. Sedimentation of soil particles may also smother fish eggs and destroy beneficial communities of bottom organisms such as bacteria (Augspurger *et al.,* 2003;Galbraith and Vaughn, 2009). Fluctuating TSS levels may influence aquatic life from fish to phytoplankton. Fine particles may carry harmful or toxic substances to aquatic life (Augspurger *et al.,* 2003;Galbraith and Vaughn, 2009).

Water salinity is a measure of the total salt concentration, comprising mostly of Na+ and Cl- ions and small quantities of other ions (Mg2+, K+, or SO42-). It is the total of all non-carbonate salts dissolved in water, as expressed in parts per thousand (1ppt = 1000mg/L or 1g/L) but is now generally expressed in parts per million (ppm). Freshwater has lower salt ion levels such as Na+ and Cl-, and these are often lower in concentration than hard-water ions such as calcium (Ca2+) and bicarbonate (HCO3-). In freshwater ecosystems, optimum salinity levels for fish growth usually less than 1000ppm. Saltwater organisms can survive in salinity levels of up to 40000 ppm, but many freshwater organisms cannot live in salinity levels above 1000 ppm (APHA, 1995). Water clarity, a direct measure of visible distance through water, is another important measure related to sediment present in the water column. Visual water clarity describes the distance that an organism can see underwater. Suspended and dissolved materials affect water clarity (Davies-Colley and Smith, 2000;NaFIRRI, 2019). Turbidity is used as a general term to describe the lack of transparency or cloudiness of water due to suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter plankton or other microscopic organisms. Historically, water clarity has been measured with a Secchi-disk, a black and white disk submerged vertically into the water until it can no longer be seen (Davies-Colley and Smith, 2000).This disk, usually 20/25cm diameter, is marked with alternating quarter sections of black and white for freshwater or is solid white for saltwater. Secchi depth measurements are generally only applicable to relatively still water bodies such as ponds, lakes, estuaries, and the ocean. Routine Secchi measurements can be very useful for identifying water clarity trends in the riverine ecosystem.

Nutrient concentrations such is Nitrates and Phosphate encourage the growth and productivity of primary producers in aquatic ecosystem (Muyodi and Hecky 2005; Allan and Castillo, 2007). Alterations of nutrient concentrations in riverine and lacustrine environments are because of anthropogenic activities such as unsustainable agricultural and industrial activities, urbanization, and domestic effluent. Increased nutrient concentration fundamentally affects food web components and faunal distribution, thus altering the system's ecosystem integrity.

2.5.2 Habitat Quality Parameters of the Riverine Systems

The habitat **is an** area habited by either terrestrial or aquatic organisms. It comprises the earth's surface structure and biological features that influence the niche's structure and energy input. Aquatic habitats further provide homage for breeding and spawning and of fish and other aquatic life. The breeding and spawning grounds and other niches required by aquatic life are only available in natural and minimally perturbed habitats (Vannote *et al.,* 1980; Wakwabi *et al.,* 2013; Orina *et al.,* 2018; Nkalubo *et al.,* 2018). To promote sustainable exploitation of riverine resources, ecologists have formulated protocols to assess the integrity of their habitats and determine the nature and degree of biotic constraints on biological communities. These assessments are relevant because the habitat supports the lotic ecosystem dynamics and ecological organization that dictates the river's biological composition (Maddock, 1999; Orina *et al.,* 2018).

The habitat condition of a stream **or a river** is, determined by the state of the **river or** stream and riparian habitat type of that ecosystem (Barbour *et al.,*1999). Its evaluation based on the diversity of flow regime, nature of the substrates, the extent of erosion and amount of woody debris, among other factors upon which stream biological community structure is built. Either the use of qualitative, quantitative criteria or both apply during habitat assessment. Qualitative habitat assessment is visual based on selected characteristics estimated in the field and rated according to the defined procedure (Vannote *et al.,* 1980). This method is advantageously executed rapidly and does not require specialized personnel.

The three commonly used qualitative habitat indices include; Qualitative Habitat Evaluation Index (QHEI) (Rankin, 1989), USEPA Rapid Bio assessment Protocols (RBP) (Plafkin *et al.*, 1989), and Riparian Channel and Environmental Inventory (RCE) (Petersen, 1992). The criteria were, applied in streams of North Dakota and those in North West Minnesota **USA.** It was found out that the indices highly correlate with each other. QHEI and RBP emphasize channel geomorphology, while RCE emphasize riparian zones. The study revealed that RBP is the most subjective as compared to the other indices. Some habitat features were overemphasized, while others diminished when using the three indices. The indices failed to predict the fish community structures in those streams (Stauffer and Goldstein, 1997).The use of a qualitative method sometimes fails to provide the study's objectivity due to biases(Poole *et al.*, 1997). A better approach of quantifying habitat characteristics was applied to increase accuracy and precision through training the data collectors in the ecosystem approaches.

Quantitative habitat assessment is obtained by measurement of stream river variables such as channel sinuosity, speed of the river, buffer coverage, and the number of riffles, vegetation cover, and the width of the river. The method uses additional equipment and resources relative to the visual-based approach. It promotes accuracy, precision, and relevancy to the study's objectives (Kaufmann and Robinson, 1998). Various authors such as Wang *et al.* (1996), Roper *et al.* (2002), Allan and Castillo (2007) described a few quantitative protocols. Habitat assessment considers the geomorphic features, water availability and flow-patterns. Attributes like the status of riverbank, riparian zone, and watershed characteristics of rivers (Binns and Eiserman, 1979; Kondolf, 2000) were assessed. These attributes are rated, scored, and summed up to determine the habitat quality index. Different metrics and scoring criteria with modifications have been applied by Barbour and Stribling (1994), M-DEQ (1997),Bain *et al.* (1999), Barbour *et al.* (1999),Kaufmann *et al.* (1999),and Rogers, (2016).

Studies conducted in several rivers and streams of the United States **America** revealed how human activities influence aquatic habitat and water hydrology (American Rivers, 2003; Somerville and Pruitt, 2004**).** In Lake Victoria basin, assessment of the integrity of River**s,** Nzoia, Nyando and Sondu-Miriu using USEPA RBP done by Raburu and Masese, (2010). This method has not been very successful in all streams because it is difficult to quantify some metrics used such as the macrophytes and macro invertebrates (Somerville and Pruitt, 2004), and the technique, therefore, remains questionable when applied (Poole *et al.*, 1997). Thus, the method has not been widely used in the riverine ecosystems in the East African region in habitat assessment. Thus studies the use of fish metrics (FIBI) have been the most recommended in the research ecological integrity in the riverine (Raburu and Masese,2010; Orina, 2018)

2.5.3 Biological Parameters

Fauna and Flora communities are used to assess the ecosystem integrity both in aquatic and terrestrial ecosystems. Such communities are macro invertebrates (Orwa *et al.*, 2013; Wakwabi *et al.*, 2013; Ojija *et al.*, 2017) and macrophytes and bryophytes (Brabec and Szoszkiewicz, 2006; Herring *et al.*, 2006; Staniszewski *et al.*, 2006) that are used in different ecosystems. Living organisms are used to assess ecosystem integrity given their preference for a particular habitat. Once the habitat is altered, their abundance, diversity, and distribution tend to change with time and space. Fish have proved to be the best bio monitors of ecosystem integrity because they are more visible, easy to identify, and can integrate the effect of watershed degradation. Fish also have a wide range of trophic levels and are valued by regulators and the public more than other aquatic organisms. These attributes make them more effective in assessing rivers' biological habitat types based on their assemblage, distribution, occurrences, and diversity (Karr, 1981; Fausch, *et al.,* 1990; Barbour *et al.,*1999; Orina, 2018).The two biological indices mostly used in the ecosystems are habitat diversity and fish index of biotic integrity. Thus, such indices are, used to estimate the diversity of the UVN.

Study done by Karr,1998 as rivers as sentinels show rivers and streams serve as a contents' circulatory system. Any changes in the landscape can end up cause an effect on the river system. Such changes can be land degradation, mining, and dam constructions. The pacific Northwest rivers have already shown signs of degradations and declines of the anadromoussalmonids and other nonanadromous native fishes due to such drivers.

Then in River Kuja fisheries is experiencing a decline due to dams, mining, and anthropogenic activities along the river. Spatial variation along river Kuja for both the HQI and FIBI showed that different activities carried out along the river have a great impact on the aquatic organisms in the ecosystem more especially the fish (Orina, *et al.,* 2018). Therefore, the application of FIBI and HQI metrics are of grate use in the fish biodiversity and population structure and water environmental variables estimates in the riverine system. Such works are of importance on the UVN system for biodiversity restoration and monitoring.

2.5.4 Biodiversity Indices

Diversity index is a quantitative measure of the number of fish species available in the community and how individual species are distributed among the groups (Raburu and Masese,2010; Orina *et al.,* 2018). The abundance and diversity of the riverine fish species are important in analysing an aquatic environment's health status. A healthy aquatic ecosystem promotes adequate and sustainable resources to its users (Flower and Cohen, 1990; Orina *et al.,* 2018), calling for regular assessment of diversity indices in aquatic ecosystems, especially the riverine environments and the UVN.

Studies done by Orina *etal.,* 2018 on Kuja rivers using fish metrics showed that fish-based index positively correlated with habitat quality index. Yet indices also correlated with fish species richness and fish population structure respectively. Then studies done on the streams of Nzovwe in Tanzania by Ojija *et al.,* 2017; using macro invertebrate metrics showed that FIBI showed a possibility of pollution in the ecosystem. Then the Shannon-Wiener diversity index showed the sampling sites were moderately polluted or possibly impaired.

Therefore, both abiotic and biotic factors influence the diversity and distribution of riverine fish assemblage. These factors include stream water level, urbanization, habitat alteration and climatic change, competition, predation, among others (Agostinho *et al.,* 2008; Orina *et al.,* 2018).Scientific research indicates that applying this tool to the riverine system and with sustainable management measures will always lead to a healthy environment hence biodiversity conservation such as the UVN, Uganda.

2.5.5 Fish-Based Index of Biotic Integrity in the Riverine Ecosystems

Fish-based index of biotic integrity (FIBI) involves using different fish characteristics to estimate ecosystem integrity (Karr, 1981). In this case it integrates various fish knowledge on assemblage, trophic level, origin, and function into a single ecologically-based index (Karr, 1981). Karr (1981) developed this method in the small streams of the United States of America by combining fish metrics such as fish community structure characteristics to develop an index of biotic integrity (IBI), referred to as a fish-based index of biotic integrity (FIBI). Fishes are suitable as bio monitors because they can infer the condition of the habitat, water quality, and biological interaction. Assessment of running water has advanced from biometric indices to a combination of multiple community descriptors and multivariate methods. Researchers have capitalized on them because fish interact with its environment for survival and existence (Barbour *et al.,* 1999; Naiman and Bilby, 1998).

FIBI integrate various fish knowledge on assemblage, trophic level, origin, and function into a single ecologically-based index (Raburu and Masese, 2010; Omar et al., 2015). The index can give a clear correlation between land use and physical habitat variables (Raburu and Masese, 2010; Omar et al., 2015). Its application is relatively simple and cost-effective. FIBI metrics were applied in various rivers such as Nzoia, Kuja, Nyando Sondu-Miriu and the Upper Victoria Nile,Raburu and Masese, (2010). For example, the FIBI developed by Raburu and Masese (2010) for rivers Nyando and Nzoia ranged from 20-25 as compared to 26-44 in the study done by Orina *et al.,* 2018 on River Kuja in Kenya. These studies showed that urbanisation, population increase along the shores of River Kuja and agricultural and mining were a key contributor to low density of FIBI in the river. Hence such drivers needed to be monitored in the UVN river for sustainability.

When assessing the integrity of any ecosystem is advisable to have a point of reference in a pristine environment. However, one of the externalities faced is that the whole river has been disturbed thus very difficult to have a point of reference from the ecosystem (Orina*et al.*, 2018). For example, in New Zealand freshwaters as pointed out by Orina *et al.,* (2018) shows that paleo-ecologists have used sediments and soil as a scoring method in determining the reference point. However, the method is costly and time-consuming.

In order to counter the challenge, prominent scientists resolved to use minimally disturbed areas with the best possible historical condition. However, sometimes the physical habitat structure might give a wrong prediction on the biological components within the reference point (Orina *et al.,* 2018). That is why it is significant to augment water quality characteristics in the assessment to understand the causes of impairment within that habitat is of high value in these studies. Hence the UVN, Uganda falls under this category of the ecosystems.

2.6The Riverine fishes and Fish populations

Some rivers support a fair number of fish communities throughout the watershed. Most of these fishes migrate from either the lake or sea to the rivers for spawning. These fishes include such as, the Clarias species, Bagrus species, Mormyridae fishes, the Tilapiines and lungfishes (Burnside, 2006; Atkins,2001). To have better management of the riverine fisheries, a need to evaluate the stock of the fish species is of value. In Uganda, most of the riverine fisheries have not been estimated in terms of stock levels. In places where monitoring has been done, it is either on Environmental and socio-economic aspects for small hydropower dams with specific terms. This omission has left a gap in the fisheries' stock level estimates in most of the rivers (Agostinho *et al.,* 2008). Fishing effort and catchability coefficients (a measure of fishing mortality) are some of the key indicators used to assess and monitor fish stocks of natural fish populations (Arreguín-Sánchez and Pitcher, 1996). This information has been generated as a basis for monitoring the impacts of dam construction on the fisheries and livelihoods of the dependent communities. This information has been achieved by establishing relationships between fishing effort and fishery yields to the fishing communities that derive livelihoods from fishing along the rivers (Arreguín-Sánchez and Pitcher, 1996). Reeves *et al.,* 1998 in the areas of watershed scale patterns if diversity indicates to us that diversity of streams fish communities increases from headwaters to lower portion of river basin. This can be done in case no alteration is done on such a system. This is an indication that species richness increases as you move downward a watershed.

Therefore, fishery yields are useful in guiding the formulation of sustainable management advice alongside other development projects such as dam construction. Changes in the numbers of the fishing fleet in each system reflect the migratory nature of fishers as fishers will always move to areas suspected to have higher fish catches. Therefore, the UVN ecosystem fisheries required diversity studies to address the population dynamics of the fisheries, water environmental variables and population structure.

2.7Dams and Impoundments and their effects on river ecosystems

During the hydropower construction is expected to pass over escarpment as water is diverted to the powerhouse (Yoshid *et al.,* 2020; Lin, 2010). Such modifications involve alterations of the local hydrology, degradation of surface water quality, increase in the siltation of the river bed and hence the resultant altered habitat may not favour fish survival especially the resident species (Lin, 2010).

Then excessive noise from development activities such as, constructions that involve rock drilling and soil/gravel transfers from one location to another and electricity generation has the potential to affect the health and wellbeing of aquatic animals as well as humans. The presence of these sounds in the aquatic environments have always affected aquatic organisms such as fish and macro invertebrates (Mbabazi *et al*, 2014; Popper and Hastings, 2009a; Greenwood, 1965; Okedi, 1971).

Some of the potential biological effects of noise on fish include physical/physiological effects, behavioural disruption and indirect effects associated with altered prey such as food for the fish that may affect the fish population. Then physical/physiological effects include hearing threshold shifts and auditory damage as well as non-auditory disruption and can directly be caused by sound exposure or the result of behavioural changes in response to sounds. Noise mainly affects younger life stages of fish such as eggs, larvae and fry (Popper and Hastings 2009a; Popper and Hastings 2009b; Wahlberg and Westerberg 2005).

Other threats in dam construction phase of the dam; migration slipway of the fishes most especially the young fish without any harm. This has been backed up by scientists; Bernasek and Marmulla (2001); whose focus was on fish mortality resulting from downstream passage through hydraulic turbines or over spillways could be significant. In addition to habitat loss or alteration, discharge modifications, changes in water quality and temperature, increased predation pressure, as well as delays in migration caused by dams. The only solutions to this can only be fish pass constructions, monitored by the aquatic team with time and space. Changes in habitat ecology affect the intolerant species. Only a few adjust drastically whereas other sensitive species are, threatened to reduction in population or gradually adapt and survive in stressed environments. However, the river damming process is intense and dramatic in that it results in habitat alterations and creation of a new ecosystem with a particular structure, biota and functioning (Agostinho *et al.,* 2008).

Scudder, (1991), also described how the biological and socio-economic productivity of flood plains are adversely affected by dam obstructions to water flow. Other studies in Rivers Zambezi,Kafue in Zambia, Tana in Kenya, Aswa high dam and River Senegal document the adverse effects of dam construction associated with power generation (Scudder, 1991). Similarly, Jackson and Marmulla (1979) documents reduced fishery yields in the Black Sea and the Sea of Azov due to impoundments on Danube, Dnieper, and Dniester rivers in Europe.

Hydropower plants are sought-after sources of power for economic developments in many countries due to their environmentally friendly nature. Hydropower dams change flow regimes, thus affect the primary production and morphological regimes of the riverine system (Yoshid *et al.,* 2020). Effects of hydropower dam projects on fish populations are ofsignificant concern to fisheries biologists, conservationists, and managers. The most common effects of such projects include changes in fish species composition, diversity, and relative abundance. While some fish populations may show massive increases in numbers, others will exhibit reductions or even extinction (Agostinho*et al.,* 2008). The barriers created by the dams obstruct the migratory patterns of aquatic organisms, including fish between the upstream and downstream sites (Agostinho *et al.,* 2008). The hindrance to fish migration in search of suitable breeding and feeding habitats negatively affects recruitments and growth. Dams lower fish species and population numbers (Agostinho *et al.,* 2008). Only the "resistant" fishes thatcan adapt to the new habitat regimes survive. Dammingalso alters the rivers physiography basins by creating distinctive zones such as the lentic or semi lentic (reservoirs) and the riverine/lotic (upstream and downstream) zones (Agostinho *et al.,* 2008).

The Upper Victoria Nile is a critical ecosystem with a rich fisheries biodiversity. The river contains most of the haplochromines fish species, some of which may not exist in the Lake Victoria. Some species like the *Neochromissimotes*haplochromines only identified in one locality in the upper Nile such as Kirindi, does not occur anywhere else. The occurrence of this species in particular areas could have been due to Nile perch predation thus decline in stock abundances (Tatum-Hume *et al.*,2018).The rich biodiversity has culminated in the population to undertake intensive exploitation for food, income, and bait for the Nile perch in the Victoria basin. In addition to the highly targeted fish such as*Mormyrus kannume*by the community as bait type for the Nile perch fishery (Mkumbo and Mlaponi, 2007). In the Lake Victoria basin, other fish such as the *Clarias* or haplochromines that are used as bait though used in low abundance(Atkins, 2001; Burnside, 2006; Mkumbo andMlaponi, 2007).Therefore,new developments on the Upper Victoria Nile fisheries, with the intensive *M. kannume* exploitation as bait in addition to source of food arelikely to affect the fish species biodiversity that to be researched on.

2.8Biology and ecology of fish populations in the UVN

The Upper Victoria Nile has a multispecies fishery dominated by the Nile perch, the Nile tilapia, the Barbus species, Bagrus species, Clarias species, *Rastrineobola argentae*, the Lungfish, *Protopterus aethiopicus* and the haplochromines (Oyango, 2004). The Nile perch (*Lates niloticus*) and the Nile tilapia (*Oreochromis niloticus*) introduced in the 1950s, in the Victoria basin system though the first major ecosystem shift only became noticeable 30 years later. When a system dominated by four species; the native Dagaa (*Rastrineobolaargentae*), *Caridina niloticus* and the exotic Nile perch and Nile tilapia (Okaronon, 1994; Kolding *et al.*, 2005;Pringle 2005;Njeru*et al.*, 2008; Downing, 2012) replaced the very diverse and complex haplochromines-based ecosystem. Since the Nile perch boom in the 1980s, its fishery has been the primary source of income for the ever-growing lakeside and the upper Nile population (Balirwa, 2007; Downing, 2012). The increase in the fisher community population has led to the demand of the fish thus some fishers migrate to the rivers such as the UVN. Most of the fishers target the Nile perch since has been used to boost the then decline Tilapiines fishery (Njeru *et al.*, 2008).

The sudden Nile perch invasion and haplochromines collapse caused major social and economic changes in the lakeside population (Downing, 2012).The increase in the Nile perch stocks led to intensive exploitation of the juvenile fishes of Clarias species, *Mormyrus kannume* and the haplochromines species from both lakes and rivers as bait (Mkumbo and Mlaponi 2007; Bassa, 2011).The UVNwas one of the ecosystems targeted in exploiting the *Mormyrus kannume*, Elephant snout fish utilized as bait for the Nile perch in Lake Victoria. The Nile perch can grow up to 125 centimetres long and live up to 14 years(Njiru *et al*., 2008; Nkalubo, 2012). It is highly treasured for its flesh and the swim bladder that fetches high price than the Nile perch's flesh.The Nile perch is a predator (Ogutu-Ohwayo, 1990; Njiru *et al.,* 2008; Bassa, 2011). Judging from the occurrence of many fish species in the stomach contents, the Nile perch might have contributed to many species' decline through predation (Ogutu-Ohwayo, 1990; Akumu, 1999). Their diet included remnants of native fish species whose populations are threatened by fish pressure, and hence prevented them from recovering. The exotictilapiines competed with the natives due to similar ecological requirements. *Coptodon zilli* used to be the most successful of the introduced species before *Oreochromis niloticus*became established (Akumu, 1999; Njiru *et al.,* 2008). It shares its nursery grounds with *Oreochromis variabilis*. Its juvenilesare in large quantities in the shallow area of papyrus swamps. Adults congregate around submerged vegetation, while younger ones mainly occur at the fringes.However, adult *Oreochromis variabilis,* on the other hand, distribute themselves on beaches of slight turbulence and high dissolved oxygen (Akumu, 1999; Twongo *et al.,* 2006). Several factors contributed to the success of *Oreochromis niloticus* as compared to the co-introduced Tilapiines. *O. niloticus* are larger, have a faster growth rate, are more fecund, have a longer life span, wider food spectrum and have less restricted habitatrequirements (Akumu, 1999;Njiru *et al*.,2008).*Oreochromis niloticus* belongs to the family Cichlids and grow up to a maximum of 70 cm total length and weighs up to 7 kilograms in Lake Victoria (Balirwa, 1998). *Oreochromis niloticus* Linnaeus, 1758 habitat type ranges 0-30 meter depth and the size increase with depth (Witte and van Densen, 1995).

The co-existence of *O. niloticus* and the Nile perch led to the increase of these two species in the Lake Victoria, including the UVN. Like other fishes globally, Nile perch is an important source of high-quality proteins and a wide variety of essential micronutrients, trace minerals, vitamins, and fatty acids (Kalhoro *et al.,* 2017; Abowei *et al*., 2010). The species is an economically important commodity with various products and by-products such as the fillets, fish maws, fish oils, fish bones and skin that support many fisher communities in Uganda and the region. The decline is attributed to overfishing due to the Nile perch species' high demand (Balirwa 2007; Balirwa 2008; Ogutu-Ohwayo *et al,* 2013; Yongo *et al.,* 2018). However, the new fishing regimes that included the use of lucrative illegal gears (Fishing rule 2010) have led to the stock decline of the native fishery, including the Nile perch from all lakes and the rivers. The decline of the Nile perch in the lakes has led the riparian people to exploit the riverine system, including the UVN to meet the demand and supply.

2.10Other Fishes of Economic importance including the Cichlids

2.10.1The Haplochromines species

The UVN connects Victoria and Kyoga, a system inhabited by haplochromines cichlids, one of the most abundant and species-rich tribes of fresh water in the world (Tatum-Hume *et al.,* 2018).Most haplochromines cichlids are found in the East African Great Lakes, which have 200 species in Lake Victoria (Tatum-Hume *et al.*, 2018).

An estimated 200 known species of haplochromines living in Lake Victoria (40%) have disappeared or threatened with extinction (Atkins,2001;Witte *et al., 2007*; Tatum-Hume *et al.*,2018) due to environmental degradation, predation by the introduced Nile perch, and recently, climatic change. The Upper Victoria Nile flow over diverse habits, including rocky areas, falls and rapids from an altitude of 1,134 meters above sea level (m.a.s.l) on Lake Victoria to 615 m.a.s.l on lake Albert (Tatum-Hume *et al.,* 2018). The Upper Victoria Nile provides habitat for the haplochromines species that underwent threat in Lake Victoria and provides habitat for species that are endemic to the ecosystem (Atkins, 2001; Tatum-Hume *et* *al.,* 2018). The developments of hydropower schemes along the Upper Victoria Nile have modified flow in the river, particularly slowing natural water flow speed in reservoir areas and likely resulted in a manifestation of secondary threats to haplochromines species. Some of the changes in haplochromines stocks in the UVN targeted fishing ofhaplochromines as baitfor Nile perch industry. The haplochromines species have been used as bait for other fish species such as the Clarias and *Mormyrus kannume* (Mkumbo and Mlaponi 2007; Bassa, 2011; Bassa *et al.,* 2018). The use of intensive gill netting and basket trapping, especially during fish migration, could have an impact on some fish species (Tatum-Hume *et al.,* 2018). Haplochromines are the preferred and main prey of large-sized Nile perch, which prefersslow-moving water habitat, including those created by hydro power reservoir. High densities of Nile perch led to a collapse in haplochromines populations while the resurgence of haplochromines led to competition and predation of Nile perch juveniles by haplochromines piscivores and larger Nile perch (Atkins, 2001; Kolding *et al.,* 2005; Witte *et al.,* 2007; Tatum-Hume *et al.,* 2018).

2.10.2The Victoria Tilapia, *Oreochromis variabilis*

Oreochromis variabilis, popularly known as Victoria tilapia, is an indigenous and critically endangered fish species of Lake Victoria(Maithya *et al.,* 2016). The habitat for this species used to be the Victoria and the Kyoga basin lakes before introducing the Nile perch (Kudongania and Cordone, 1974; Okaronon, 1994).

The Victoria tilapia, *Oreochromis variabilis* belongs to the family of cichlids and is one of the fishes harvested on the Upper Nile. However, its population is considered at high threat according to IUCN’s red list (Twongo *et al*., 2006). Victoria tilapia, *Oreochromis variabilis* is one of the native species in the African lakes and rivers (Maithya *et al.,* 2016; Wasonga*et al.,* 2017). This species is one of the endangered species on the African continent (Twongo, 2006; Maithya *et al.,* 2016).*O. variabilis*, once commercially fished in the Kyoga and the Victoria basin systems, since the 1980s become rare to near endangered status (Okaranon 1994; Katunzi and Kishe, 2004; Twongo *et al.,* 2006; Ogutu–Ohwayo *et al.,* 2013). A study in Lake Victoria, Kenya,to increase the productivity of the tilapiines and conserving the genome of *O.variabilis* in the ecosystemproved that*O.variabilis* could hybridize with other Tilapiinessuch as*Oreochromis niloticus andCoptodon zilli* (Maithya *et al.,* 2017).*O.variabilis*was successfully farmed in controlled ponds environment using formulated diets (Maithya *et al.,* 2016). Though these studies are ongoing, there is a need for the conservation of *O. variabilis* in the aquatic ecosystems. *O. variabilis* has suffered a considerable reduction in its destruction and is believed to be restricted to e.g., small satellite lakes.It is also believed to have been virtually eliminated from its original range in Lake Victoria and Kyoga through predation, competitive aggression, and ecological displacement by introduced fish species thushave been registered as critically endangered (Twongo *et al.,* 2006; Maithya *et al.,* 2016).

2.10.3Other Fishes in the Upper Nile

The UVN has other fishes that are utilized by the fishers as a source of income and food although their population sizes may not be compared to the fishes such as the Nile perch and the Nile tilapia. Some of the fishes are the Barbus species, the Clarias species, the Synodontis species and the Bagrus species. Other fishes include the *Brycinus sadleri*,Dagaa, *Rastrineobola argentae* and the *Protopterus aethiopicus* (Onyango, 2004). The *Bagrus docma*c belong to the family of Bagridae. This species is dominant in Kyoga and Victoria lakes, including the Nile system (Witte and van Densen, 1995; Basiita *et al.,* 2016*).Bagrus docmac* predominantly is piscivores that include larger invertebrates. The growth rate is estimated at L_∞ at 82.5 cm, K=0.08 yr^{-1}. The stocks of *Bagrus docmac* species have decreased in the Lake Victoria basin with the introduction of the Nile perch (Witte and van Densen, 1995).*Labeo barbusaltinialis* that belongs to Cyprinidae is one of the species that inhabit the upper Nile. Most of these species are native species in the Victoria basin. Studies done on Lake Victoria showed four of the major commercial taxa Haplochromis spp, *Bagrus docmac, Clarias mossambicus* and *Synodontis victoriae* and one minor genus (Xenoclarias) were eurybathic Kudhogania and Cordon, (1974 a and b) and Okaranon, *et al.,* (1999). On the other hand, Tilapia spp, *Protopterus aethiopicus* and most commercially minor categories were oligobathic. Tilapia spp, *Oreochromisesculentus* has the widest, and *Oreochromis leucostictus* the narrowest depth range of distribution. Kudhogania and Cordon, (1974 a and b) carried out the depth zone limits of these species is as follows: *Protopterus aethiopicus*(50-59 m), *Oreochromis esculentus* (40-49 m), *Oreochromis variabilis* (30-39m), *O. niloticus* and *Coptodon zilli* (20-29 m) and *Oreochromis leucostictus*are confined to waters not more than 10 m deep. *Barbus altinialis*known as the Ripon barbell is one of the potentially high-value fish species threatened with overexploitation (Witte and van Densen, 1995;Aruho *et al.,* 2018). A large cyprinid grows up to about 90 cm total length and 10 kg individual weight (Witte and van Densen, 1995;Aruho *et al.,* 2018). The species is widely distributed in the Lake Victoria region and many rivers and streams, except in Lake Albert (Witte and van Densen, 1995; Aruho *et al.,* 2018). *Labeobarbus altinialis* and *Bagrus docmac* are high-value demanded fish species, which have great potential to generate incomes in local and international markets and provide nutritional benefits for the local communities. These species are distributed in some areas of the Upper Victoria Nile since it is connected to Lake Victoria (Aruho *et al.,* 2018).

The small pelagic cyprinid, *Rastrineobola argentae* (Pellegrin) from the Cyprinidae family, commonly known as dagaa, accounted for 60% of the total fish biomass and 40% of the commercial catches in Lake Victoria in 2015 (Mageni *et al.*, 2018). In Lake Victoria, dagaa is the only native fish species that persisted and expanded into a dependable and sustainable fishery after the lake's ecological transformation in the 1980s. The dagaa fishery, that had been harvested (at the beginning of the 20th Century from inshore areas using traditional papyrus seines and long cone-shaped basket traps was done mainly by women for domestic consumption) (Witte and van Densen, 1995; Mangeni-Sande*et al.*, 2018). Dagaa was later exploited commercially by light fishing using traditional kerosene pressure lamps. Overtime, these fishing methods were replaced by catamaran technology from the 1990s (Witte and van Densen, 1995). The catches of dagaa expanded in three phases (1980–1990, 1991–2004, and 2006–2015), with total catches doubling during every transition. Whereas fishing effort both in terms of the number of fishers and fishing boats also doubled at every transition (Kolding *et al.*, 2014; Mageni *et al.*, 2018).These high catches could only besustained by a proportional increase in biomass. *Rastrineobola argentae* populations have been in the Upper Victoria Nile since time memorial. However, the modifications of the upper Nile, in terms of damming has led this species' increase in abundance, thus competing favourably with other species in the ecosystem. This study addresses the stock levels of the species in catches and annual estimates in relation to other species in the UVN.

2.11Growth, Mortality and Recruitment Patterns of fish species.

Growth, mortality, and recruitment parameters are essential for the assessment and management of fish stocks. These parameters determine the total catch and annual **variations** of fish exploited in the fishery resources (Abowei *et al.,* 2009;Welcomme *et al.,* 2010;Kalhoro *et al.,* 2013).Several causes of mortality include diseases, pollution, spawning stress and changes in the water levels due to the river modifications (Abowei *et al.,* 2009).In rivers, Fish mortality is a major factor in determining the number of fish able to recruit into the mature stock. This principal is based on the following; adequate food resources; achieving a sufficient size to reduce predation and achieving sufficient size seasonally (Science Report, 2014). In any fishery as recruitment is going on, exploitation of the same fishery by the fisherfolk impinges on the stock sizes. The exploitation rate (E) enables one to assess the stock effectiveness in terms of overfishing and determining the sustainable yield of the fishery. Meanwhile, the recruitment is the entrance of the young into the exploiting fishing area and become liable to contact with fishing gear. Recruitment is the major variability in fish populations (Agostinho *et al.,* 2008; Sparre and Venema,1998). In rivers, habitat destruction, alterations of the ecosystems and unregulated change in water volumes have always led to migrations of the fish stocks, recruitment effects and even population collapse or disappearances in intensively regulated stretches (Agostinho *et al.*, 2008). Studies in Mekong rivers showed at 877 species occurred in this ecosystem. Out of these 103 have been impacted on by the hydropower dam thus a reduction in total biomass by 0.3% (1700t/year) hence recruitment effects on the fishery (Yoshid *et al.,* 2020). Such circumstances have also happened in the UVN that needs attention.

Scientists have indicated that knowledge of length-weight relationships is an important tool for the adequate management of any fish species which have been applied in the assessment of fish stocks and populations. It is also useful in local and interregional morphological comparison of populations. Length-weight relationship data of fishes are useful for biologists in fishery assessment and proper management of their population. It has been widely used in fish biology with several purposes: to predict weight from length measurements for yield assessment, to calculate the standing crop biomass, to estimate weight at age, stock assessment, to evaluate index of well-being of fish population, to assess age structure and function of fish populations, growth studies, to assess fish population dynamics and growth, to make morphometric comparisons between species and populations and life history comparisons between regions (Asadi *et al.,* 2017; Sparre and Venema, 1998). Therefore, such predictions are vital in the UVN fisheries resources.

2.12 Food and Feeding Interactions of the fishes

Food plays a big role in the aquatic organisms' survival, growth, migration patterns and breeding, including fish (Nkalubo *et al.,* 2018). The low abundance of the aquatic organisms that are taken as food hasalways led to the fish migration patterns from one location to another in search offood within the aquatic ecosystem (Lin, 2010; Nkalubo *et al.*, 2018). Some of the drivers that could lead to low macro-zoo benthos organism are the modifications of the UVN due to dam constructions, leading to siltation, lagoon destruction, and loss of sheltered bays.The alterations of the invertebrate community may cause fish migration and changes in fish community structure. This shift could have led to pollution and eutrophication of the aquatic ecosystem, causing an effect on the invertebrate community structure, which is one of the food contents for the *O.variabilis* species and other herbivorous fishes (Mwebaza-Ndawula,1994; Sekiranda *et al.,* 2004; Vincent *et al.*, 2012; Ngupula, 2013**).** For example, a study undertaken on Lake Victoria by Mwebaza-Ndawula, 1994, showed that as it consisted of micro-macro invertebrates such as Cyclops copepod, Cladocera and *Caridina nilotica* and Chaobrus larvae. Observations showed that the species community structure were being affected by eutrophication, predation, and changes in food web in the ecosystem. Then the study undertakes by Sekiranda *et al., 2004*; in Murchison Bay in Lake Victoria some of the Macro invertebrates some of which were tolerant meanwhile others were not.*Hydrocarina* (Water mites) were some of the species that were not tolerant in the ecosystems as compared to species such as the Leeches, Worms and Chironomids. Tolerance and intolerance species are also observed in the fish species (Karr, 1981). Therefore, there is need to understand the food and feeding interactions of the important fishes of the UVN in understand the growth patterns and recruitment.

Storing or diverting water dams alter the natural distribution and timing of stream flows. This in turn changes sediment and nutrient regimes and alters water temperature and chemistry, with consequent ecological and economic impacts. Reduction in downstream annual flooding affects the natural productivity of floodplains and deltas. These ecosystem impacts result in a significant impact of dams on freshwater biodiversity, which is already under special threat (Yoshid, 2021, Bergkamp, *et al.,* 2000. At the global scale endangered freshwater fish estimated to reach 30% of the known species. North America detailed studies indicate that dam construction is one of the major causes of freshwater species extinction. In this case, multiple dams on a river significantly aggravate the impact on ecosystems. Sediment entrapment can reach 99% if a cascade of dams is developed (Bergkamp *et al*., 2000). Generally, fish migration is affected by either single or multiple dams.

It has been observed that the Northern hemisphere 77% of the largest rivers are affected by dams and on many rivers fully natural reaches are restricted to headwaters (Bergkamp *et al*., 2000). The global impacts of dams on the global water cycle are increasingly recognised. And such impacts could also be affecting the aquatic life of the UVN including the fisheries.

2.13Bait fishery in UVN; casestudy of the Elephant Snout, *Mormyrus kannume*

The Elephant snout fish, *Mormyrus kannume* belongs to the Mormyridae family. And is one of the indigenous and dominant fishes, in African lakes (Witte and van Densen, 1995, Ragheb, 2016); is intensively exploited both as bait and food by the riparian community.Some preliminary studieswere carried out on the nature and function of the electric organ in the *Mormyrus kannume* (Witte and van Densen, 1995; Ragheb, 2016). This organ helps this fish in terms of being sensitive to the environment and used as a protective measure from attack.

The Elephant snout fish is long-lived species. It can grow up from 60 to 156 cm in total length (Witte and van Densen, 1995; Ragheb, 2016) in the river Nile systems. This fish species is highlyexploited from the Upper Victoria Nile. The fishing methods for the Elephant snout fish on the upper Nile have been undergoing modifications based on the supply and demand by the riparian communities. Currently, the fishery is highly exploited using the basket trap from the previous gillnets that used to be the main gear.

In the Ugandan culture, the Elephant snout fish,which was historically preserved for men,currentlyconsumed by all sexes, and play a role in food security (Witte and van Densen, 1995; Okedi, 1971). Besides the intensive exploitation, using basket traps on the Nile River for bait is rampant. The Elephant snout fish has been widely studied in the lower Nile of the waters in Egypt (Ragheb, 2016; Mekkawy and Hassan, 2012) though there is scanty information from the Victoria Nile. The Elephant snout fish is a bottom feeder and feeds on macroinvertebrates such as Ephemeroptera, Povilla, Caridina nilotica, Chironomids and Chaobrus larvae and other microorganisms (Ragheb, 2016; Mekkawy and Hassan, 2012).Due to its feeding mechanism, the fishers in the Upper Victoria Nile have designed a new mechanism of the basket traps to increase its capture. The exploitation has intensified due to the utilization of this fish as bait for Nile perch from Lake Victoria and being a source of food.The effects and impacts of the dam on the fisheries and the level of exploitation are not well understood.Therefore, this study aimed to address the spatial and temporal abundance of the bait fishery of the fishes in the UVN, focusing on *Mormyrus kannume*.

2.14 The UVN in its perspectives and knowledge base.

The UVN is one of the rivers on the African continent that exhibit various fishes that contribute to the income and food to the riparian fisher community in the region. Such fishes are the Nile perch, the Nile tilapia,*M. kannume*plus others in small quantities like the *Bagrus docmac, Labeo barbus altinialis* (Aruho *et al*.,2018; Basiita *et al*.,2016). The UVN also acts as a central storage for the fishes that might not be existing in Lake Victoria because of the Nile perch predation such as some of the haplochromine fish fishes (Tatum-tume *et al.,* 2018). Besides that, management and scientific studies of the fishery have been focused on the lake ecosystems and almost none on this river that has culminated to intensive fish of the fishes of the UVN. Thus, scanty information found in the UVN that could not help in the management and restoration systems of the ecology the stock of the UVN. Therefore, this study was undertaken to address habitat quality in relation to physico-chemical parameters and fish community structure in the UVN whose information is currently not known. Then determine the population dynamics of fish in the UVN and mainly focusing the commercial fishes such as the Nile perch, the Nile tilapia, *M. kannume*, and the critically endangered fishes such as *Oreochromis variabilis* whose niche is mainly the Nile. In addition to that the study had to focus on the trends in fishing effort and fish catches in the UVN and the spatial and temporal abundance of the bait fishery of the fishes in the UVN, focused on *Mormyrus kannume*as the main target fish species in the ecosystem. The impacts of the dam on the stock abundances and their composition both upstream and downstream. The main aim was to address scientific background of the UVN that would help in the fisheries restoration and conservation of the ecosystem including the fisheries of the UVN.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Areas

This study was undertaken in the Upper Victoria Nile (Figure 3-1), covering the Bujagali areas of the ecosystem.The river has other streams that flow into it and some small rivers, thus making it expand as it flows towards Sudan. Some of the streams are the Bugungu, Masese, Kalagala, and Nalwekomba that flow into the main river. It has both slow and fast flowing stretches like Bujagali falls that is taken up to construct the dam. The Upper Victoria Nile region has various developments such as the old Owen falls, a second dam at Bujagali falls and a third at Isimba falls the Isimba dam. The Owen Falls Dam power production capacity is 180 Megawatts and the Kiira Dam, 200 MW, Bujagali Dam, 250 MW and below the Upper Victoria Nile, there are two dams undergoing construction. These dams are projected to produce power as follows; Isimba Dam 180 MW and Karuma Dam 600 MW. In addition to these power dams there are industries such as Nile Breweries, Paper-manufacturing factory (PAPCO), Steel rolling mills and Nile Garments factory constructed along the upper Nile stretch. The developments mentioned above, unsustainable agricultural practices such as tilling of the land up to the riverbanks, use of fertilizers and pesticides and deforestation contributed to the catchment’s degradation. These activities result in poor water quality that affects the general ecology of the riverine ecosystem, including the fisheries.

It is in this UVN ecosystem that a study was undertaken based on the criteria of site identification before samplings were done in these areas. The criteria for identifying the sampling stations were based on the following. (i) Accessibility on either side of the riverbank since not all areas were accessible due to the topography of the banks and the very fast flow regime of the river. (ii) Status of fishing activities at selected sites. (iii) Proximity upstream or downstream of the developmental projects such as hydroelectric power site. (iv) Coverage of many habitats. (v) Representativeness of the Upper Victoria Nile ecosystem.

Biannual data was collected from 2014 to 2019 that targeted long and short rains. This data was compared with secondary data collected from 2008 to 2013 of fisheries and environmental sampling on the UVN. The study areas were in a transect form that is upstream, middle, and downstream of the Bujagali dam.

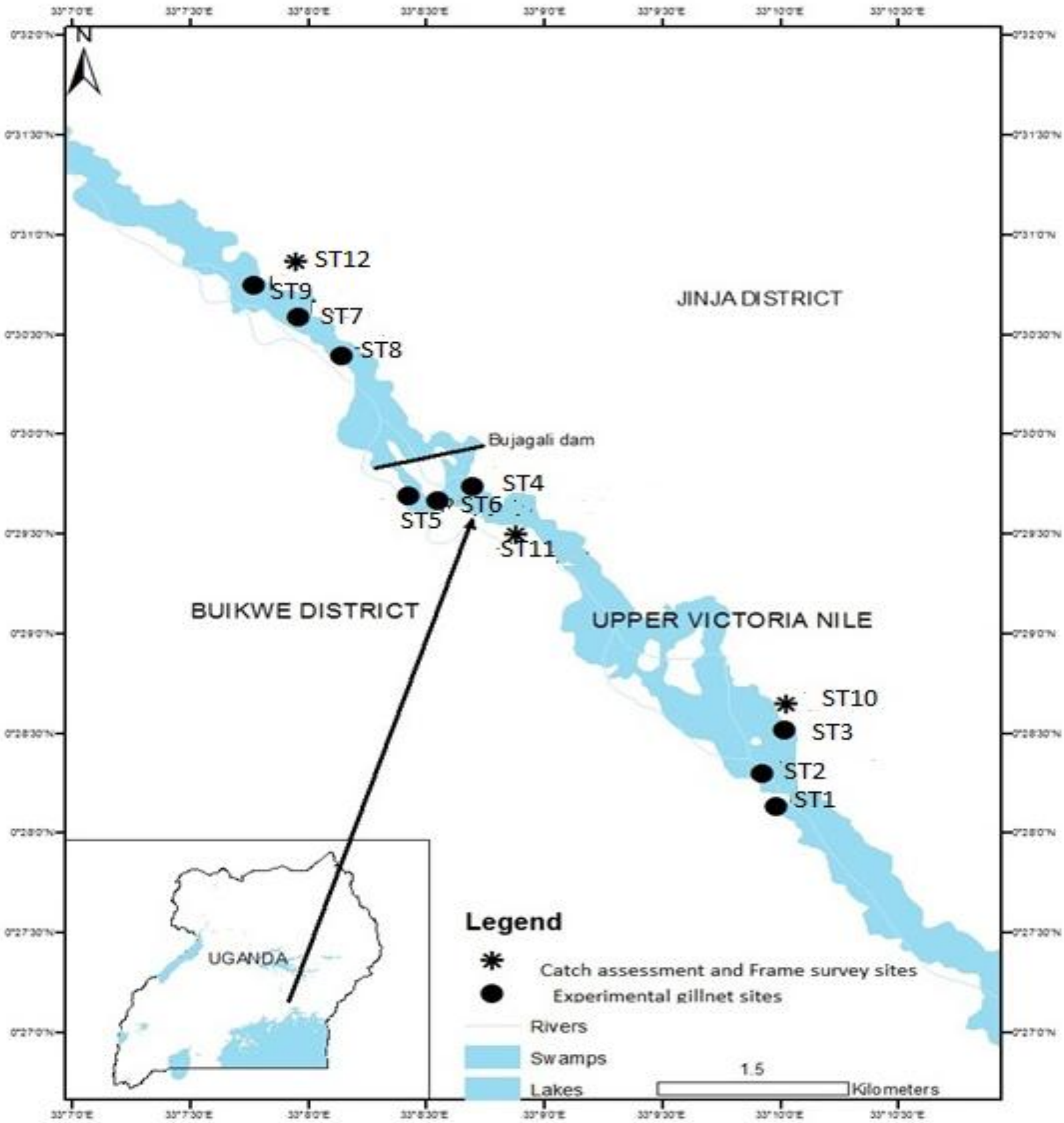

Figure 3-1: Map of Upper Victoria Nile showing the sites where Habitat, Fish diversity, Water quality, catch assessment and Frame survey studies were recorded (Inset: Map of Uganda showing the location of the Upper Victoria Nile, used QGIS to develop)

3.2 Sampling design for Habitat Quality (Habitat quality index) and Ecosystem Quality Indices (Fish index of biotic integrity)

The estimation of habitat quality index followed a standard protocol described in Raven *et al.* (1989). Sample data collection was designed based on the transects that were set based on the criteria (Table 3-1). The transects were upper, middle, and lower transects. The upper transect covered (S10, ST1, ST2, ST3), middle (ST11, ST4, ST5 and ST6) then lower transect were (ST12, ST7, ST8, ST9) (Figure 1-3). The estimation of habitat quality index followed a standard protocol described in Raven *et al.* (1989) and adopted by Orina *et al.* (2018). The scoring criteria are. The metrics used were; the river depth, the width of the stream, channel and natural buffer vegetation, number of riffles and channel sinuosity, river bed substrate type, bank erosion profile, aesthetic of the value and in-stream cover (snags, woody debris, holes at the banks and macrophytes and speed of the water.

Table 3-1: The scoring criteria for habitat characteristics (referred from Raven *et al.*, 1989; Rogers, 2016)

Habitat parameter	Scoring criteria			
Available in-stream cover of the fish score	Abundant >50% substrate that favours colonisation	Common 30-50% limited	Rare 10-29.9% disturbed substrate	Absent <10% lacking
	4	3	2	1
Bottom substrate score	Stable >50% gravel or larger substrate	Moderately stable 30-50% gravel or larger substrate	Moderately unstable 10-29.9% gravel or larger substrate	Unstable <10% gravel or larger substrate
	4	3	2	1
Dimension of largest pool score	Large Pool covers	Moderate Pool covers	Small Pool covers	Absent No riffles
	4	3	2	1
Number of Riffles score	Abundant >5 riffles	Common 2-4 riffles	Rare 1 riffle	Absent No riffles
	4	3	2	1
Water level score	High <5% if channel substrate is exposed	Moderate Water fills >75% of the channel	Low Water fills 25-75%	No Flow Very little water in the channel
	4	3	2	1
Channel sinuosity score	High Well defined bends	Moderate 1 well-defined bend	Low Water fills 25-75%	No Flow Very little water in the channel
	3	2	1	0
Bank stability score	Stable	Moderately stable	Moderately Unstable	Unstable
	3	2	1	0
Riparian Buffer Vegetation	Extensive Width of the natural Buffer is >20 meters	Wide Width of the natural buffer is 10.1-20 meters	Moderate Width of the natural buffer is 5-10 meters	Narrow Width of the natural buffer is <5 meters
	3	2	1	0
Aesthetics of reach score	Wilderness Outstanding natural beauty	Natural Areas Trees or native vegetation	Common setting Area is developed	Offensive Clutters; may be a dumping area
Total score	3	2	1	0

Then the estimation of ecosystem quality indices (Fish index of biotic index) sampling design was based on the same methods of samplings. The criteria for sites selection were based on the same procedures mentioned in 3.1 of the study areas. Samples were collected in the month of April and September on yearly basis from 2014 to 2019 targeting both long and short rains

The metrics used for data collection were; species richness and community composition, trophic guild, abundance, and composition. This information output was based on fish habitat types from the experimental gillnets set in these sites from (25.4 to 203.2 millimetres), set in replicates per sampling twice a year capturing both long and short rains for a period from 2014 to 2019 in the months of April and September. The scoring criteria for the ecosystem quality (Fish index of biotic index) (Table 3-2). The sampling stations were characterized as exceptional, high, intermediate, limited and or minimal integrity index for ranges 26-31, 20-25, 14-19, 8-13, <7, respectively.

Table 3-2: FIBI metrics and its scoring criteria (Referred from (Karr, 1981, Raburu and Masese, 2010 and Orina *et al.*, 2018)

Category	Metric	Scoring criteria		
		1 (worst)	3	5(best)
Species richness and composition	No. of native species	<3	3-5	>6
	No. Intolerant species	<3	3-5	>6
	No. of rheophilic species	0	1	>1
	% of benthic species	<7.5	7.5-15	>15
	% of tolerant individual	>20	10-20	<10
	% of Cyprinidae individual	<40	40-80	>80
Trophic metric	% of detrivores individual	<7.5	7.5-15	>15
	% of carnivores individual	<1	1-4.4	>4.5
	% of omnivores individual	>45	20-45	<20
Abundance and condition	No. of individual per 50m of	<25	25-50	>50
	sampling-transect	>2	1	0
	No. of exotic species	<1.25	1.25-2.50	>2.50
	Modified index of well being			

3.3Sampling Research Design for Water parameter and population dynamics of the fish

The study employed qualitative and quantitative approaches.The study area was divided into three sampling sections assumed to represent the diversity of potential influences of the damand the UVN. These sites were theupstream of the dam, the reservoir area and the downstream of the reservoir (dam). Within these sections, fishery-dependent and fishery-independent data collection were undertaken to provide the full range of fishery characteristics and fish biometric data respectively. Alongside these experiments, habitat characterization of the river sections in the study area was undertaken using observational techniques and standard methods for water quality studies.The nine stations (ST1,2,3,4,5,6,7 and 8) (Figure 3-1)were designated experimental fishing sites with gillnets of mesh sizes ranging from 25.4-203.2 mm as the main sampling gear. Water parameters were collected in the same stations. The stations were (ST1) at 0.47524^{o}N, 33.16699^{o}E and (ST3) 0.46856^{o}N, 33.16578^{o}E and (ST2) 0.47164^{o}N, 33.16541^{o}E all located approximately 6 km upstream of the Bujagali hydropower station on formerly Dumbbell Island which is now submerged by the newly constructedBujagali hydropower dam. These sites lie downstream of the Kiira/Owen falls dam. Five islands occur within this area of the sampling transect (Figure 3.1).

In the middle of the UVN, the three sampling stations were, (ST6) 0.494807^{o}N, 33.140473^{o}E, (ST5) 0.494400^{o}N, 33.142469^{o}E, and (ST4) 0.495601^{o}N, 33.144980^{o}E. The sites were in the surrounding villages of Namizi and Buikwe at Malindi. Due to various constructions in this area, the habitat was rocky with few shrubs surrounding the environment. However, due to ecological changes that could occur after the dam construction especially on the fisheries and other aquatic organisms, this site was, identified to monitor changes in the fisheries in relation to both upstream and downstream of the dam. The site location was approximately 1kilometre above the Bujagali dam.

The lower three habitat**s**, fish community structure and water parameters sampling stationswere (ST7) 0.50973^{o}N, 33.13263^{o}E, (ST8) 0.50654^{o}N, 33.13568^{o}E, and (ST9) 0.512440^{o}N, 33.129490^{o}E, approximately 1 km downstream of Bujagali dam. Steep banks characterized this zone on both sides of the river channel. There are rocky beaches and the shoreline for the most part was free of stable vegetation cover. The, transect was chosen because of its characteristic steep banks on both sides of the river. Some of the aquatic plants (*Phragmites australis* and *Vossia* species few Water hyacinth (*Eichhornia crassipes*) are present. Below this site is swift-moving waters with many rocks. Naminya, Kisadha, Ofwono, Zaire, Mugalya, Kisoga are the villages associated with the site. Sampling was replicated at eachsite twice a year in April and September for the period 2014-2019.

3.4 Sampling Research design for Trends in catches and effort

Trends in catches and effort studies were; designed to be collected in three sampling stations. The sampling stationswere (ST10) 00.4748^{o}N, 33.16634^{o}E located in the Upper Victoria Nile of the Bujagali dam in areas of Kalange village, Budondo subs county, Jinja district, Uganda the middle site located at Bujagali dam reservoir, (ST11) 0.49157^{o}N, 33.147970^{o}E and(ST12), 00.50733^{o}N, and 33.13124^{o}E (Figure 3-1). In these sites, data of catch and effort was collected to achieve the trends in catches of the fish species of the UVN.

3.5 Sampling Design for Bait Fishery

The major landing sites for the bait fishery that mainly targeted the *Mormyrus kannume* were located atST10, ST11, and ST12. Then for the growth and mortality parameters for *M. kannume,* site's location was ST1, ST2, ST3, ST4, ST5, ST6, ST7, ST8 and ST9 (Figure 3-1). The sampling procedure for the bait fishery was based on the same way as it was illustrated in study area of 3.1. These were; (i) Accessibility on either side of the riverbank since not all areas were accessible due to the topography of the banks and the very fast flow regime of the river. (ii) Status of fishing activities at selected sites. (iii) Proximity upstream or downstream of the developmental projects such as hydroelectric power site. (iv) Coverage of many habitats. (v) Representativeness of the Upper Victoria Nile ecosystem. These experiments were done in the months of April and September, annually, that is, during long rains and short rains.

3.6Data Collection Procedures

Data collection utilized in the sampling sites presented in the above research design involved the following: physico-chemical characteristics, biological data, and catch and effort data sets from the Upper Victoria Nile for the whole sampling period.

3.6.1 Collection of Physico-Chemical Data

In-situ measurements of physico-chemical parameters such as Oxygen (DO), pH, Temperature ^{o}C, Total depth (SD) and Conductivity were determined using a multi-parameter probe Wissenschaft-Technische Werkstatten (WTW) German-made hand-held portable probes of types: WTW oxi330 for oxygen concentration and WTW pH 197-combined pH and temperature electrode or a hydrolab. All the probes were first, calibrated according to the manufactures' manual. Water transparency was determined using a Secchi disk on the shaded part of the boat.

The in-situ measurements were done in the nine sampling sites as designed in the study these were from ST1 to ST9 (Figure 3-1). Sampling was done in morning hours starting from 7:00 a.m. to 11:00 a.m. when the water parameters have not changed. Data was collected based on profile methods such as depth range interval from the surface then an average was taken in accordance to site. Samples were collected in the nine sites with depth variations of 0.8 to 31.32 metres. The lowest depth levels were in the recorded insites ST7 and ST3with 0.8 meters and highest in the reservoir in site ST3 with 31.32 meters. Data was collected per site per day and twice a year in the months of April and September from 2014 to 2019.Total suspended solids (TSS) samples were collected in a high density polyethylene (HDPE) 1 L container. Then after that was connected to vacuum pump to the side arm of the vacuum flask. In that period, you will be required, seat your filter holder in the top of your vacuum flask or use a manifold for increased numbers of simultaneous samples and higher efficiency. Then, place a pre weighed filter paper in the filter holder, wet it with a small amount of reagent water to seat it, and secure the funnel to the base. After that, filter as much sample as is possible within a 10-minute span, up to 1 L. While the sample is filtering, record the pan ID and initial weight from the label on the pan. Record the total sample volume filtered. Later, wash the filter and collected solids with three successive 10 mL portions of reagent water. This will remove any dissolved solids trapped in and on the filter. Suction for about three minutes after filtration is complete was done. Then the filter placed back in its pan and place in a drying oven set at 104±1°C for at least one hour.Filters/pans from the oven and removed and placed in a desiccator until they reach room temperature. Then later, weighed each filter on a balance to the nearest 0.0001 g and record the weight. Note: Do not include the pan in this step. In most cases reweighing can be done more times as are necessary in order to obtain a reading ±0.0005 g from the previous weight. Then later, result calculated with the following equation:

$$\frac{\text{Weight final (g)} - \text{Weight Initial (g)} \times 1{,}000{,}000}{\text{Sample volume}} = \text{TSS mg/L}$$

The final weight (Wtf) is the weight of the filter plus the dried residue and the initial weight (Wt i) is the weight of the unused filter.The outputs from physico-chemical equated to the National Environmental Management (NEMA) standards of Uganda to see if they were in permissible ranges.

The following are the NEMA permissible ranges as follows; Oxygen 3.0mg/l; pH lower NEMA std 6 and Upper NEMA std 8; Temperature, lower std 20^{o}C and upper std 35^{o}C, Conductivity (us/cm), TSS,100mg/l; Total nitrogen (TN), Total phosphorus (TP), Ammonia (NH4-N) 10,000 ug/l, Nitrate (No3-N) 20,000ug/l and Phosphate (Po4-P) 5,000ug/l (NEMA SOPs, 1999).

3.6.2 Determination of water Samples

To determine the nutrient concentrations, water samples were collected in prewashed (with double distilled water) 250 ml borosilicate bottles. The water samples were placed in an icebox and taken to the National Fisheries Resources Research Institute laboratory in Jinja for analysis. All samples for the determination of nutrient concentration were filtered through 47 mm diameter GFC glass fibre filters of pore size 0.47 micrometres. The determinations of nutrient concentrations followed the detailed protocol described in APHA (2005).The nutrient concentrations determined were: Total nitrogen (TN),Total phosphorus (TP), Ammonia (NH4-N), Nitrate (No3-N) and Phosphate (Po4-P).The measurements were done using a spectrophotometer (Jenway 6505 UV/VIS: Spectrophotometer) model 6505 voltage 230/115V.

3.6.3 Determination of Ammonium

Ammonium nitrogen determination was carried out using the phenol hypochlorite method (APHA, 2005). Except under very alkaline conditions (pH >9), most of the ammonia (NH_3) in freshwater exists in the ionic form (NH4+). Ammonia reacts with phenol and hypochlorite under alkaline conditions to form indophenols blue. The colour intensity was proportional to the concentration of ammonium within an ammonium nitrogen concentration in a range of 0-1000µg. Colour intensity (absorbance) was measured with a spectrophotometer at 630 nm using highly purified water as a blank (APHA, 2005). On the procedural basis, preparations of duplicate 100ml aliquots of ammonia standard samples were prepared for analysis. Then 50ml of distilled and denoised water, ammonia standards in50ml stoppered graduates were measured. Then 2 ml of phenol reagent was added mixed thoroughly then later 2.0 ml of Sodium nitroprusside reagent s added. After that 5.0 ml of the oxidising reagent (the alkaline solution made of Sodium citrate 100g and sodium hydroxide 5 in 500ml of distilled and deionised water). Then the sample was left for 1 hour after which measurements were done with a spectrophotometer at 630 nm using highly purified water (distilled water) as a blank (APHA, 2005 and APHA, 1998). Data collected was tabulated and then regression done using excel sheets.

3.6.4 Determination of Nitrates

The nitrates in water were quantitatively converted to nitrites when the sample were runthrough a cadmium reduction column. The nitrites produced were then quantified by the diazotization method (APHA, 2005). A buffer solution was added to 50mL of a filtered watersample and ran through a cadmium reduction column. The final 25 ml of the water sample wasanalysedby adding 0.5 ml of each of sulphanilamide and N-1-Napthylethylene hydrochloride solution, allowed to stand for 2-8 minutes, and absorbance read at a wavelength of 543 nm.

3.6.5 Determination of Total Nitrogen (TN)

Samples for total nitrogen (TN) were analysedusing the hydrazine reduction technique (APHA, 2005).The method involved the oxidation of TN with alkaline persulphate to nitrate. 10 mL of an unfiltered water sample was mixed with 50 mL of digestion solution and mixed in closed borosilicate bottles and autoclaved for 30 minutes at a temperature of 121°C.The digestion process converted all nitrogen forms to nitrate nitrogen, whose concentration was determined using the cadmium reduction method. Cadmium-copper reduction column prepared as follows. Prepare filings for all columns in one batch. In here, place 5 g of cadmium filings in a beaker, wash with 25 mL of 2 N HCI and rinse with deionized water. Then, add 10 mL of cupric sulphate solution and swirl until all copper is deposited until blue colour disappears. After which, plug bottom of column with a small piece of glass wool, fill column with water and add treated cadmium to a point level with the outlet. There should be no entrapped air bubbles. Then finally flush column twice with a solution of 50 mL of 01 plus 5 mL of buffer solution (5g of cadmium with 25mil of 2 N HCL). Adjust metering valves so that the delivery rate for 25 mL is 240 seconds +/- 10 seconds. In this case, cadmium columns should be regenerated and stored in buffer. (APHA, 2005)

3.6.6 Determination of Soluble Reactive Phosphorous

Soluble reactive phosphorus (SRP) was measured using the ascorbic acid method (APHA, 2005). The method primarily measures phosphorus in the form of orthophosphate (PO4-P). Under acidic conditions, phosphorus forms a yellow complex with molybdate, which slowly reduces to a blue colour by ascorbic acid. To a 50mlwater sample, 5ml of mixed reagent containing (ammonium molybdate solution, sulphuric acid, ascorbic acid, and potassium antimony tartrate) was added and left standing for 5 minutes. Light extinction of the solution was measured with a spectrophotometer (Jenway 6505 UV/VIS: Spectrophotometer) model 6505 voltage 230/115V, at a wavelength of 880nm (APHA, 2005).

3.6.7 Determination of Total Phosphorous

Total phosphorus (TP) was determined using the persulphate digestion method (APHA, 2005). The method involved the oxidation of all forms of phosphorus to orthophosphate by autoclaving 10ml known amount of an unfiltered sample at 121 °C at 15 psi for 30 minutes using the persulphate catalyst. The resulting orthophosphates were analysedby the ascorbic acid method. In order to obtain ascorbic acid, dissolve 2.5 g of L-ascorbic acid in 100 mL of distilled deionized water. This reagent is stable for a few days if kept refrigerated. (APHA, 2005; Wetzel and Likens, 2000, LVFO, SOPs,2004).

3.6.8 Determination of Flow Rate/River discharge

The flow rate was estimated using an oval object. An orange was placed in the water at each specified distance, time was recorded and the average of the distance by the time taken.The rate of water flow was computed by dividing the time taken by a float to cover a defined distance of 10 meters on the river of the UVN. River width, depth intervals taken and used in the habitat studies.

3.6.9 Collection of Habitat Quality Indices data

River depth was measured using an echo sounder (depth finder) Model Hondex PS-7 LCD digital sounder and GPS readings using the Model GPS MAP 64S GARMIN from nine sampling sites across the river. Then average estimate values for river depth in sampled areas were recorded. The width of the river was measured using GPS, channel, and natural buffer vegetation recorded. The number of riffles and channel sinuosity were counted, observed, and recorded. Riverbed substrate type was recorded from material obtained from Ponar Grab Model Petite Ponaro (R) 6" SCOOP-08890 WILD COCR.Bank erosion profile, and aesthetic value and in-stream cover (snags, woody debris, holes at the banks and macrophytes) was visually examined and recorded. These metrics were used to estimate the habitat quality index (Rogers, 2016; Orina *et al.*, 2018; Raven *et al.*, 1989; Ranklin, 1989) (Table 3-1).

The different scores of the metrics at each sampling site were summed up to give a total score. Then the range of the HQI index was obtained for the upper Nile. The sampling stations were characterized as exceptional, high, intermediate, limited and or minimal integrity index for ranges 26-31, 20-25, 14-19, 8-13, <7, respectively. The analysis was done using Excel spreadsheets.

Table 3-3: The scoring criteria for habitat characteristics (referred from Raven *et al.*, 1989; Rogers, 2016; Orina *et al.*, 2018)

Habitat parameter	Scoring criteria			
Available in-stream cover of the fish score	Abundant >50% substrate that favours colonisation	Common 30-50% limited	Rare 10-29.9% disturbed substrate	Absent <10% lacking
	4	3	2	1
Bottom substrate score	Stable >50% gravel or larger substrate	Moderately stable 30-50% gravel or larger substrate	Moderately unstable 10-29.9% gravel or larger substrate	Unstable <10% gravel or larger substrate
	4	3	2	1
Dimension of largest pool score	Large Pool covers	Moderate Pool covers	Small Pool covers	Absent No riffles
	4	3	2	1
Number of Riffles score	Abundant >5 riffles	Common 2-4 riffles	Rare 1 riffle	Absent No riffles
	4	3	2	1
Water level score	High <5% of channel substrate is exposed	Moderate Water fills >75% of the channel	Low Water fills 25-75%	No Flow Very little water in the channel
	4	3	2	1
Channel sinuosity score	High Well defined bends	Moderate 1 well-defined bend	Low Water fills 25-75%	No Flow Very little water in the channel
	3	2	1	0
Bank stability score	Stable	Moderately stable	Moderately Unstable	Unstable
	3	2	1	0
Riparian Buffer Vegetation	Extensive Width of the natural Buffer is >20 meters	Wide Width of the natural buffer is 10.1-20 meters	Moderate Width of the natural buffer is 5-10 meters	Narrow Width of the natural buffer is <5 meters
	3	2	1	0
Aesthetics of reach score	Wilderness Outstanding natural beauty	Natural Areas Trees or native vegetation	Common setting Area is developed	Offensive Clutters; may be a dumping area
Total score	3	2	1	0

3.6.10 Collection of Estimation of Fish Index of Biotic Integrity (FIBI) data

The FIBI metrics were categorized into three groups or categories. The first category comprised species richness and composition. The category is further subdivided into species richness, the number of native species and the percentage of tolerant and intolerant species. This categorisation helped to assess the level of pollution to the aquatic ecosystem because ofchanges in the dominance level of biota due to pollution (Moyle, 1994; Tafangenyasha and Dzinomwa, 2005; Orina *et al.*, 2018). In a polluted ecosystem, tolerant biota tends to dominate over the intolerant species.

The second category constituted trophic guilds. This metric data collected included the number of fish: omnivores, piscivores, detrivores, and carnivores. In this category, the number of feeding guildswas recorded. The occurrences and distribution of fish were influenced by changes in food availability. The change is because of nutrient alteration that follows the principles of the Serial discontinuity (Ward and Stanford, 1983; Naiman and Bilby, 1998).

The third category consisted of the abundance and condition of the fish caught. The abundance metric considers the number of individual fish caught per 50 m of sampling in a transect form. The abundance metric is important in determining the pristineness of a habitat. Natural ecosystems tend to have a high abundance of native fish species and vice versa. It was assessed by determining the level of hybridization and alteration from normality. Since this method is expensive and sophisticated, it was substituted by determining the fish abundance of introduced species and estimatinga modified index of well-being to estimate the extent of impairment. In an impaired ecosystem, exotic species become more successful than the indigenous species. Oberdorff and Hughes (1992) assessed the condition of fish by determining the deformities, eroded fins, lesions and tumours (DELT) in a fish. This method was not fruitful in Africa because no data werecollected over the same assessment (Ross, 1991; Toham and Teugels, 1999; Sharm *et al.*, 2013). Raburu and Masese (2010) modified the index of well-being (MIWB) in the Victoria basin to assess the health and condition of the fish. The above three categories were scored using the criteria described by Karr (1981), adopted by Raburu and Masese (2010) and used by Orina *et al, (*2018) (Table 2). Below is the table showing how the metrics were scored to estimate the FIBI. The scoring criteria was based on the fish taxonomy of the fishes, the trophic guild, then the fish abundances.

Each metric was scored and a summation computed using Excel. The stations were characterised as excellent, good, fair, poor, or very poor depending on whether it was within the range of 50–60, 40–49, 30–39, 20–29, and < 20, respectively.

Table 3-4: FIBI metrics and its scoring criteria (Referred from (Karr, 1981, Raburu and Masese, 2010 and Orina *et al.*, 2018)

Category	**Metric**	**Scoring criteria**		
		1 (worst)	**3**	**5(best)**
Species	No. of native species	<3	3-5	≥6
richness and	No. Intolerant species	<3	3-5	≥6
composition	No. of rheophilic	0	1	>1
	species	<7.5	7.5-15	>15
	% of benthic species	>20	10-20	<10
	% of tolerant	<40	40-80	>80
	individual			
	% of Cyprinidae			
	individual			
Trophic	% of detrivores	<7.5	7.5-15	≥15
metric	individual	<1	1-4.4	≥4.5
	% of carnivores	>45	20-45	<20
	individual			
	% of omnivores			
	individual			
Abundance	No. of individual per	<25	25-50	>50
and condition	50m of sampling-	≥2	1	0
	transect	<1.25	1.25-2.50	≥2.50
	No. of exotic species			
	Modified index of			
	well being			

Habitat quality indices were examined for the period sampled. Similarly, FIBI indices of biological integrity for the sampled period were calculated using excel. A final range was extracted from the individual ranges. Biodiversity indices used as metrics in the estimation of fish indices of biological integrity was computed using the following formulae. The percentage contribution of individual species was estimated using the formula

$$Percentage\ contribution = {}^{number\ of\ indivisual\ fish\ population/}_{total\ number\ of\ fish\ in\ a\ community}\ x100 \ldots\ldots\ldots\ldots \quad \text{(i)}$$

The condition factor, which was used to assess the health status of fish, was estimated using the following formula:

MIWB=0.5lnN+0.5lnB+HN+HB……………………………………………...(ii)

Where: - ln – Natural log, N- Number of fish individuals caught per unit distance sampled, B- Biomass of fish individuals caught per unit distance excluding tolerant and exotic species, HN- Shannon-wiener diversity index based on fish numbers, HB- Biomass respectively. MIWB – is the modified index of wellbeing.

The information recorded regarding the number of species, biomass, and abundance was used to estimate the diversity of fish species at every station (Peet,1974; Flower & Cohen 1990; Krebs, 1999). Four biodiversity indices (Shannon-Wiener, Simpson, Species evenness and Species richness) were computed using the following formulas:

Shannon-Wiener's diversity index formula;

$H = -\sum_{i=1}^{s} piln(pi)$---(iii)

Evenness index

E_H=H/lnS --(iv)

Simpson index of diversity

Simpson index of diversity = 1-D

$D = \sum_{i=l}^{s} Pl^2$ --(v)

Where: pi - the proportion of individuals calculated as number of individuals' species divided by the total number of individuals in the community sampled. In – the natural log, S- the number of species, H- Shannon index of diversity, D-Simpson index.

Species richness

The number of occurrences of the individual fish species in a sample during the whole period of samplings.

3.7Collection of Population dynamics datasets

Population dynamics studies data were collected using gillnets. Experimental sets of gillnets were used to collect fish samples in the identified sampling sites. Gillnets are always rectangular in shape. On the upper edge, the head rope has floats and has sinkers on the footrope. Gillnets can either drift or can be set stationary and can be set in form of gangs of nets of different mesh sizes (Sparre and Venema, 1998). Gillnetsare passive gears, which effectively catch any fish bigger than their mesh sizes encounters. In this case, fish can be snagged, where the mesh is placed just behind the eye. The gilled fish, is one caught along the gills or wedged in the mesh and fish caught around the body in front of the dorsal fins or entangled (Sparre and Venema,1998). Three fleets of gillnets of mesh sizes ranging from (1) inch (25.4mm) to eight (8) (203 mm) in an increment of ½ inch up to 5.5" andothers of 6, 7 & 8" were set in each sampling site. The nets were set at each of the three experimental sampling sites in each sampling locality for a period of two days. The nets were set at 6:00 pm and retrieved at 6.00 am.

Fish samples from gillnets were sorted out into species and the mesh size in which they were caught. Individual weight per fish specimen, using an electronic balance scale Model CS-10KWP-IP65 to the nearest 1g was measured. Since the electronic balance only weighed fish up to the maximum of 5000g, the weight of fish above the latter wasweighed using a balance that could measure weights up to 20 kilograms. A measuring board of 100 centimetres was used to measure total, fork and standard length to the nearest 0.1-cm. Fish species were identified using Greenwood (1966), Witteand Van Densen(1995), Axelrod, 1969 and Ole Seehausen,1999).

In the laboratory, the fish were dissected to determine the sex and observe the type of food eaten. Stomach contents were preserved in 5% formalin and analysedusing an inverted microscope model XSZ-H at magnification X50 and X100. The food items were identified and points were allotted to different degrees of stomach fullness according to Hynes (1950) and adopted by Hyslop, (1980) and Aruho *et al.*(2018)to give the stomach's fullness index. The contribution of food items relative to all food items in the gut was determined through visual judgment.

The sexual maturity stages of 1-6 were scored and recorded (Witte & Van Densen, 1995;LVFO; 2005; Brown-Peterson *et al.,* 2011;Aruho *et al.,* 2018).The number of each fish species at each sexual maturity stage was identified recorded. Thesedata were laterused to determine the length at which 50% of the population was mature. Further, the size of the smallest mature fish for both males and females were recorded at each sampling. Fish were dissected and sexed. Sexes were determined for only those fish whose gonads were identifiable as male and female, and maturity stages of fish were assigned from stage I to VI according to a method described by Witte & Van Densen (1995); LVFO, (2005) and Brown-Peterson *et al.,* 2011.Fish in stages I, II and III were regarded as immature, whereas those in stages IV, V, VI and VII were regarded as mature. All this was done by hand sexing method.

3.8 Length Weight relationship of fish species

The length-weight relationship of the most dominant fishes in the UVN was, calculated by the power function equation. $W= aL^b$ ……………….. (vi). Where "W" is the total weight (g), "L" is the total length (cm), "a" is the intercept and "b" is the slope (King, 1995; Aruho *et al.*, 2018). The Fish stock assessment Tool version II (FISAT II) was applied for data analysis (Gayanalo and Pauly, 1997; King, 1995, Aruho *et al.*, 2018).

3.9 Fish Population Structure and Diversity

Analysis of fish species diversity of UVN focused on fish species composition and distribution in the sampled sites. Catch per gill net mesh size per day by fish species were calculated. Strata of the area with the gillnets set were put into consideration. To calculate mean abundance, the numbers in the different samples were calculated and averaged across all sampling sites using excel. Catch per unit effort (CPUE); expressed, as Number/gear/unit time was determined for each fish species (LVFO, 2007a).

3.10 Growth parameters

Asymptotic length (L_∞), growth coefficient (K) and the parameter t_o of the von Bertalanffy equation for growth in length were estimated using ELEFAN methods in FISAT II (Ricker, 1971; Sparre and Venema, 1998; Gheshalghi *et al.*, 2012; Yongo *et al.*, 2018).

$L_t = L_\infty(1\text{-exp-}K (t_o\text{-}t_1)$ ………………… (vii), were estimated using the ELEFAN methods. In addition, the parameter t_o, that is the time the length t is zero or time of birth was calculated using the formula:

$Log_{10} (-t_o) =-0.3922-0.2752log_{10}L_\infty-1.038log_{10}K$ ………………………………. (viii)

The maximum age of the fish was calculated using the formula:

$t_{max}=3/k+t_o$ ……………………………………………………………….. (ix) (Sparre and Venema, 1998; Yongo *et al.*, 2018).

The growth performance indices of the fish species studied were estimated using the formula: ɵ $=\log_{10}k+2\log_{10}L_\infty$ …...... (x)(Sparre & Venema, 1998; Yongo *et al.,* 2018).

3.11 Beverton and Holt's Yield-per-Recruit and Biomass per recruit

The relative yield-per-recruit model was based on the Beverton and Holt (1966) model, as modified by Pauly and Soriano (1986)and applied by Yongo *et al*, (2018). The options assuming knife-edge selection were utilized using probabilities of capture. Inputs were of L_c/L_∞ and M/K ratios. Relative yield-per-recruit (Y'/R) were computed from the relationship:

$$\frac{Y'}{R} = EU^{M/k}\left\langle 1-\frac{3U}{(1+m)}\middle|\frac{3U^2}{(1+2m)}\middle|\frac{3U^3}{(1+3m)}\right\rangle \ldots\ldots\ldots\ldots\ldots\ldots \text{(xi)}$$

Where $U=1-(L_c/L_{\infty});\ _{M(1-E)}/(M/K)=(K/Z)$; and E=F/Z……..(xii)

Relative biomass per recruit (B'/R) was, estimated from the relationship:

$$\frac{B'}{R} = \frac{(\frac{y}{R})}{f} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(xiii)}$$

While E_{max}, $E_{0.1}$ and $E_{0.5}$ were estimated using the first derivative of this function. E_{max} is the exploitation rate at maximum sustainable yield (MSY). $E_{0.1}$ was the rate at maximum economic yield (MEY), and $E_{0.5}$ was the optimum exploitation rate.

3.12 Estimation of Mortality rates

Total mortality rate for each species was estimated using the linearized catch curve equation based on length data as described by Sparre and Venema (1998).

Z=F+M ……………………………………………………………………… (xiv)

Where: F is fishing mortality and M is Natural mortality.

The Natural mortality (M) was estimated using Pauly's empirical formula whereby: $\ln M = (0.0152 - 0.279*\ln L_\infty + 0.6543 * \ln K. +0.463* \ln T)$. ………………….. (xv)

Where L_∞ is the length at infinity, K is growth constant, and T is the mean temperature of the water body.

The fishing mortality was obtained by subtracting the natural mortality (M) from the total mortality (Z), F=Z-M……………………………………………………. (xvi)

The exploitation rate for each species was estimated as E = F/Z. …………… (xvii)

Where: F stands for fishing mortality, M for natural mortality, E for exploitation rate, and Z for total mortality.

3.13 Length at First Maturity of fish species

The length at 50% (L_{50}) of fish in a class size sexually mature was estimated from the ratio of the coefficients of a binary logistic regression of length and maturity level. These coefficients (α & β) of the binary regression were estimated by Excel-solver statistical program in Excel micro software (Windows 7 professional). The length L_{50}=Alpha (α)/Beta (β), where α and β were the coefficients of a two-parameter non-linear model (Aruho *et al.,* 2018; Bassa *et al.,* 2018; Nkalubo, 2012) obtained by stabilizing the coefficients and fitting the logistic ogive curve using the Excel-solver. The two-parameter logistic ogive was described by the non-linear equation: $PL=1/[1+exp^{(\alpha - \beta L)}]$……….. (xviii)

Where: PL was the predicted proportion of mature fish at the length of the fish L. α and β were coefficients of the parameter model. Fishes in the developing phase (stages II and III) and above (stages IV, V, VI, and VII) were considered mature (Brown-Peterson *et al.,* 2011; Aruho *et al.,* 2018). A regression between length and weight was run using Excel Microsoft to predict the corresponding weight at L_{50} for TL (cm). Comparisons of coefficient *b* of power equations were based on Froese (2006). To obtain the size-frequency distributions (number of sampled fish in each size class) for each size class for data collected from each site, individual sizes of fish were grouped in intervals of 2 units using a pivot table in Microsoft Excel. The Nile perch, Nile tilapia and Elephant snout fish sizes graphs were plotted against the class intervals obtained.

3.14 Fish stomach/ gut analysis

Samples from the stomach of important fish species were analysed. The food content (prey taxa) was grouped based on the length class of the fishes and relative abundance and percentage frequency were calculated. The food types were subjected to a chi-square test to determine significant differences. The statistical tests were performed with SPSS Version 20.0. Differences in sex ratios of major riverine fishes' species from the UVN were estimated using a chi-square method to determine if the ratios were significantly different from the hypothetical 1:1 female to male ratio (Aruho *et al.,* 2018). The fish gut analysis was obtained based on literature (Omondi and Ogari, 1994; Raburu and Masese, 2010; Omondi *et al.,* 2013; Aruho *et al.,* 2018). The samples were further categorized into either tolerant or intolerant, according to Hugueny *et al.* (1996), Toham and Teugels (1999) and Raburu & Masese (2010) under FIBI and HQI.

3.15Effort and Catch Data collection

Data on catch and effort were collected using catch assessment and frame survey stations in three, as mentioned above. Catch assessment surveys (CAS) are aimed at the harvest sector to generate information relating to fish catches and fishing effort (LVFO, 2007b; LVFO, 2007c; Bassa *et al.,* 2014). At the selected landing sites,all the fishing boats were sampled since most of them has less than 20 boats of whom you are supposed to, stratify by Vessel/boat gear type randomly accordance to standard operating procedure (LVFO, 2007c). The SOPs indicate**s** that sampling should be 20 vessels based on the vessel gear combination at each landing site**.** Data collected from the fisher's catches included the fish species, total length (cm), total weight (kg), gear type, the number of crew per vessel and the vessel type, total value of fish (UgSH).

The frame survey data collected at each landing site included the total number of vessels, number of crew, gear type, mesh sizes and the number of each target fish species, vessel type, model of propulsion and the number of days fished in a week. The aim of collecting this data was to estimate the total fish landings in the Upper Nile. The weight of each fish species landed was recorded separately.

CAS data were used to estimate total annual landings, percentage composition by species, catch rates, and the average cost of each fish species per kilogram weight. Catch per unit of effort was estimated. Estimates of CPUE were required for monitoring the relative abundance of species *i* in period *k*, and the effort corresponding to a single gear type *j* used according to the following formula

$$CPUE_{i,j,k}\left(\frac{kg}{unit} of\ effort\right) = \frac{Total\ catch\ of\ species i, taken\ by\ gear j, in period}{Fishing\ effort\ of\ gear j, in\ period\ k} \quad \text{(xix)}$$

The average values of fish per kilogram was computed over on annual basis to establish changes in annual prices. The total landings per day were obtained by summing up the amount of fish caught in each landing site, multiplied by the number of fishing days per fishers in a week, and summed up for all fishers at each landing site and for all the three landing sites. This analysis made it possible to obtain the total amount of fish landed in the upper Nile region in one week. To get the total landings in a month, the total landings in a week were multiplied by the number of weeks in a month. To get the annual landings, total landings in a month were multiplied by the number of months in a year. During the total landing, each species' weights was computed for each week, month, and year. The species composition of each fish species was then computed on an annual basis by dividing the weight (in kilogram) of the species by the total annual landings of species multiplied by hundred. Annual trends of total landings, species composition and catch per unit of effort were plotted using an excel program. Length frequency for the species, Nile perch (*Lates niloticus)*, Nile tilapia (*Oreochromis niloticus),Oreochromis variabilis and Mormyrus kannume* were plotted and represented in the results.

3.16 Bait fishery data collection

Data on the bait fishery included the type of bait, the quantity of fish landed, the price of fish landed targeted as bait, and the fishing gear used. The main fishery on the UVN ecosystem was the Elephant snout fish *Mormyrus kannume* (Plate 3-1) .

Plate 3-1: *Mormyrus kannume* from the Catch assessment Upper Victoria Nile, Uganda. (UsingAndroid SM-G900L, camera)

The target fish were weighed in kilograms and forkal length in centimetres taken per individual species.To determine the growth parameters, the following was done: the fish was dissected to quantify the sex, fat content and gut analysis by food type in addition to individual forkal length of the fish. Therefore, data for bait type was collected using the two methods, of catch assessment and the biological parameters used in the experimental gillnets.

The Elephant snout fish (*Mormyrus kannume)* caught by fishers in the Upper Victoria Nile has always been used as bait for fishing the Nile perch. Hence, the total amounts of *Mormyrus kannume* harvested were used to develop a plot indicating changes over time. Catch rates per gear per day were calculated. Annual estimates and value on temporal basis were computed using excel. The statistical tests of ANOVA were performed using SPSS Version 20.0.

3.17Data Analysis Procedure

3.17.1 Physical and Chemical Parameters

Data collected wereentered inexcel worksheet, and cleaned to remove outliers.These were transferred to Statistical Package for the Social Sciences version 20 (IBM SPSS statistics 20) software for tabulation and analysis. Descriptive statistics using mean, variance, standard deviation, and standard error were determined. Data generated for the physico-chemical parameters such as Oxygen, Secchi depth, pH, Temperature, and nutrient datasets were input directly and tabulated. The mean values of physico-chemical parameters among sampling sites were compared using analysis of variance (ANOVA). Tukey's post hoc test using SPSS wereused to identify the pairs of sampling points in which there were significant differences in the parameters measured. A Principal Component Analysis (PCA) was performed on the resemblance matrix to identify the pattern of environmental variables; PERMANOVA was used to test the differences in the groupings along the sampling stations using PRIMER7+PERMANOVA.

3.17.2 Recruitment and Yield analysis of Fish Species

Growth parameters, $L\infty$ and K were used as inputs by backward projection along a trajectory that is the vonBertalanffy growth equation (VBGF). This projection occurs on the frequencies onto the time axis of a time-series of samples. Plots illustrate the seasonal recruitment patterns. ANOVA was applied to test the significant difference among the sites and assumed normal distribution of the data. Trends in the size structure of the fish species for the period sampled were analysedwith spatial and temporal. This analysis was aimed at determining whether there was any change in the population structure of the riverine fishes in relation to the environmental variables.

3.17.3 Percentage composition and stomach/gut analysis of fish species

The food types were subjected to a chi-square test to determine significant differences. The statistical tests were performed with SPSS Version 20.0. Differences in sex ratios of major riverine fishes' species from the UVN wereestimated using a chi-square method to determine if the ratios were significantly different from the hypothetical 1:1 female to male ratio (Aruho *et al.*, 2018).

3.17.4 Analysis of growth and mortality parameters

The growth and mortality parameters were analysed using ELEFAN methods in the Fish Stock Assessment Tool version two, FISAT II developed by Pauly (Sparre and Venema, 1998).

3.17.5 Analysis of Catch and Effort data

Fish catches, and mesh sizes were tabulated for mean length and standard error. Statistical tests using ANOVA and Post hoc in SPSS Version 20.0 were undertaken.

3.17.6 Analysis of Bait data

Annual estimates and value temporal basis were computed using excel. The statistical tests of ANOVA were performed using SPSS Version 20.0.

CHAPTER FOUR

RESULTS

4.1habitat Quality and Ecosystem Integrity In Relation To the Physico- Chemical Characteristics and Fish Community Structure.

This objective presents the findings for physico-chemical parameters, habitat quality index, fish community structure and fish-based index of biotic integrity of the Upper Victoria Nile Bujagali area.

4.1.1 Spatial and Temporal variation of Physico-Chemical parameters

4.1.2PHof water in UVN

The lowest mean pH was recorded at (ST2) with a pH value of 7.30 ± 0.12 while the highest at (ST3) with pH value of 7.79±0.13 (Figure4-1).On the spatial scale, there wasno significant variation (F=0.780; df=107; p=0.621) between stations at the Upper Victoria Nile (Appendix 11).On the temporal scale, the mean pH ranged from 7.14 ± 0.10 in 2016 to 8.05 ± 0.24 in 2018 (Figure 4-2). Correlation matrix recorded out on the pH using Pearson Square at 0.05 level of significance. The One-way ANOVA recorded significant variation (F=4.811; df =43; p=0.000) between years (Appendix 10). These findings were compared with results from 2008 to 2013 that indicated that pH ranged from 6.86±0.07 to 7.78±0.08 (Figure 4-3).

4.1.3 Temperature (T^oC) of water in UVN

The mean temperature varied from 26.03± 0.24˚C at ST1 to 26.35± 0.20˚C at the lower areas of the river after the reservoir in ST9. There was a fluctuation trend from (ST1) towards the lower sites (Fig. 4-4). On the temporal scale, the mean (T^oC) ranged from 24.97 ±1.01 in 2019 to 26.98 ± 0.21 in 2015 (Fig. 4-5). The one-way ANOVA recorded no significant variation

(F=0.449; df =107; p=0.669) between sites and yet was significant (F=3.316; df =43; p=0.014) between years. The results were compared with the results from 2008 to 2013 that indicated that temperature (ºC) ranged from 25.32±0.06 to 27.02±1.02 (Figure 4-6).

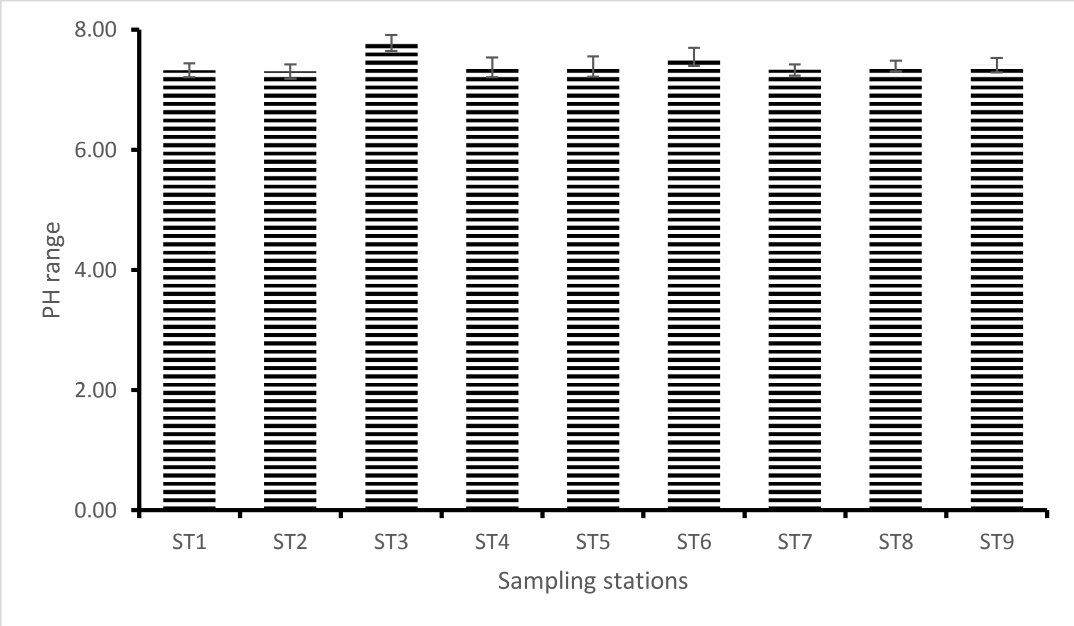

Figure 4-1: Mean pH (± SE) at different sampling stations on UVN

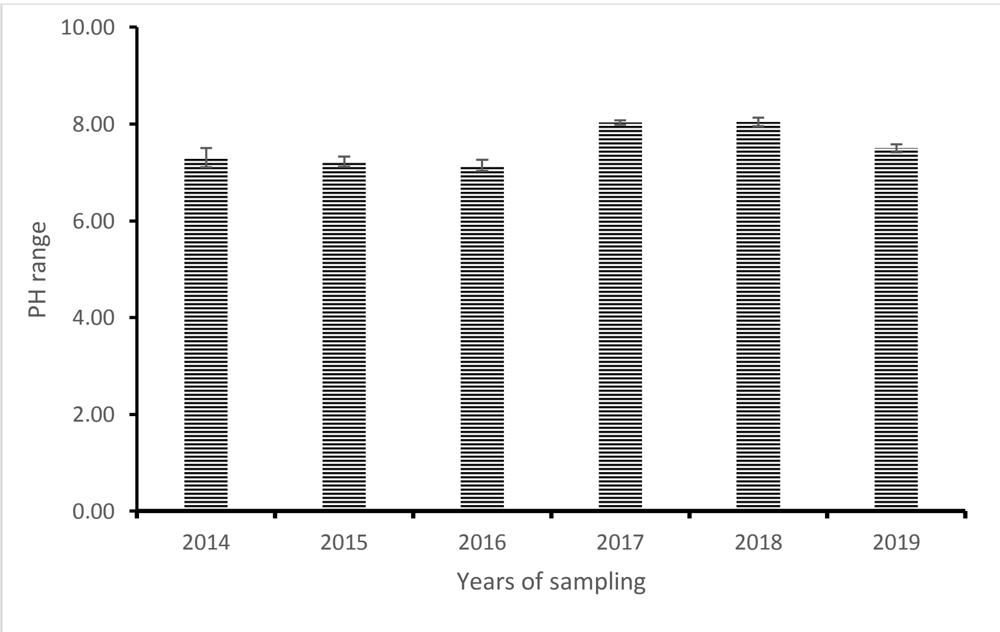

Figure 4-2: Mean pH (± SE) at different period of sampling of 2014-19 on UVN

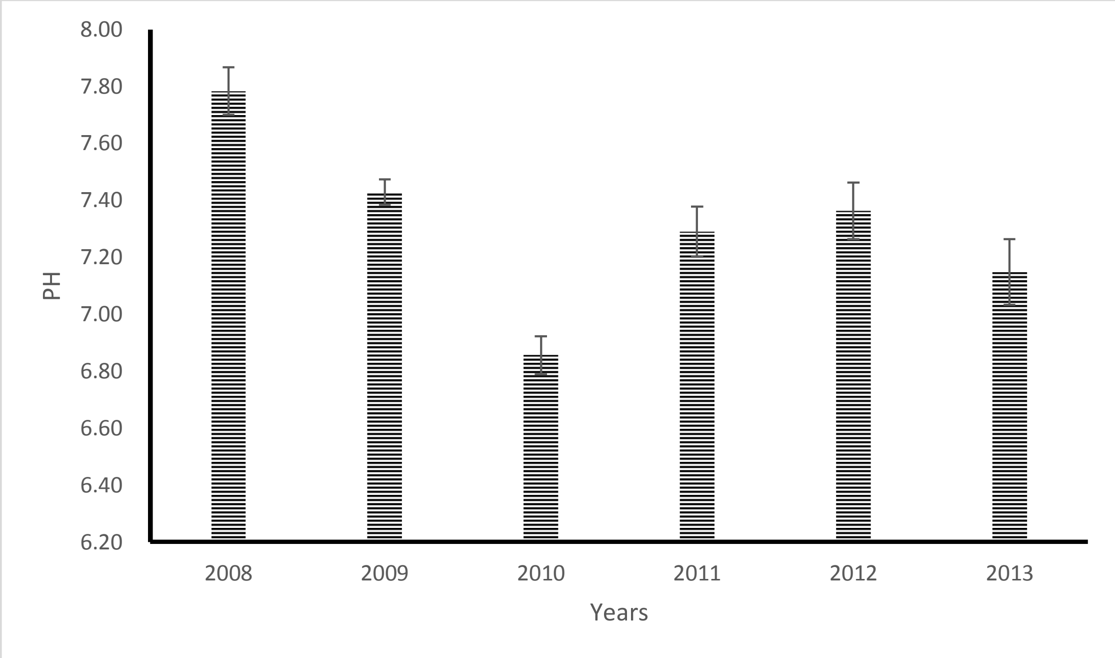

Figure 4-3 Mean pH (± SE) at different period of sampling of 2008-13 on UVN

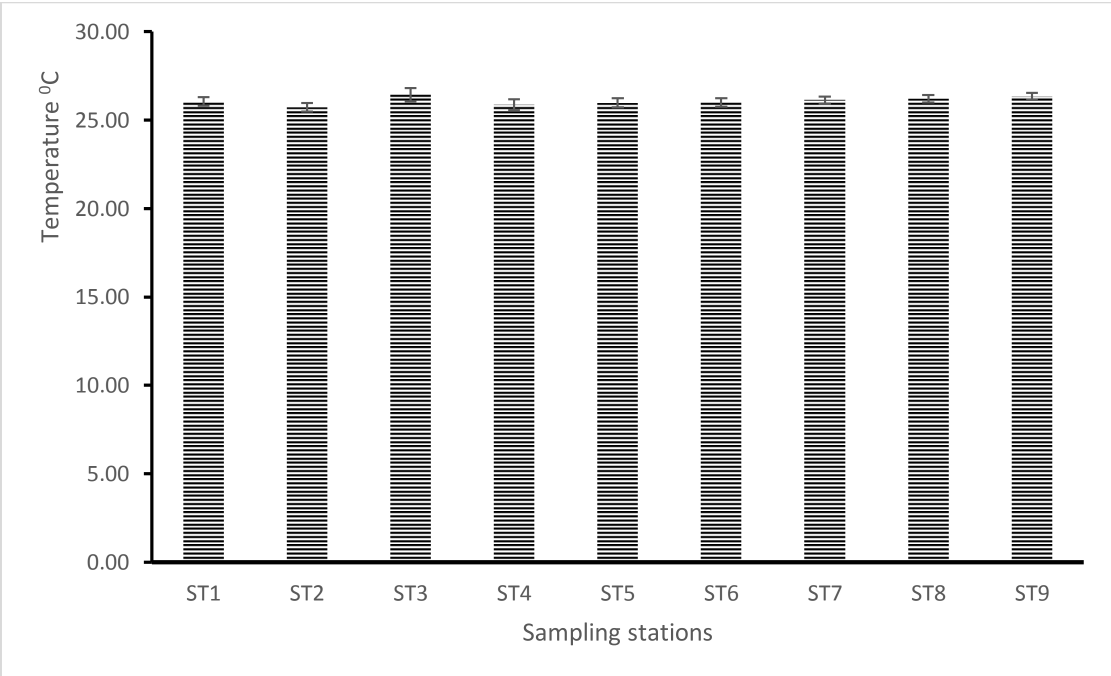

Figure 4-4: (T^{o}C) (± SE) at different sampling stations on UVN

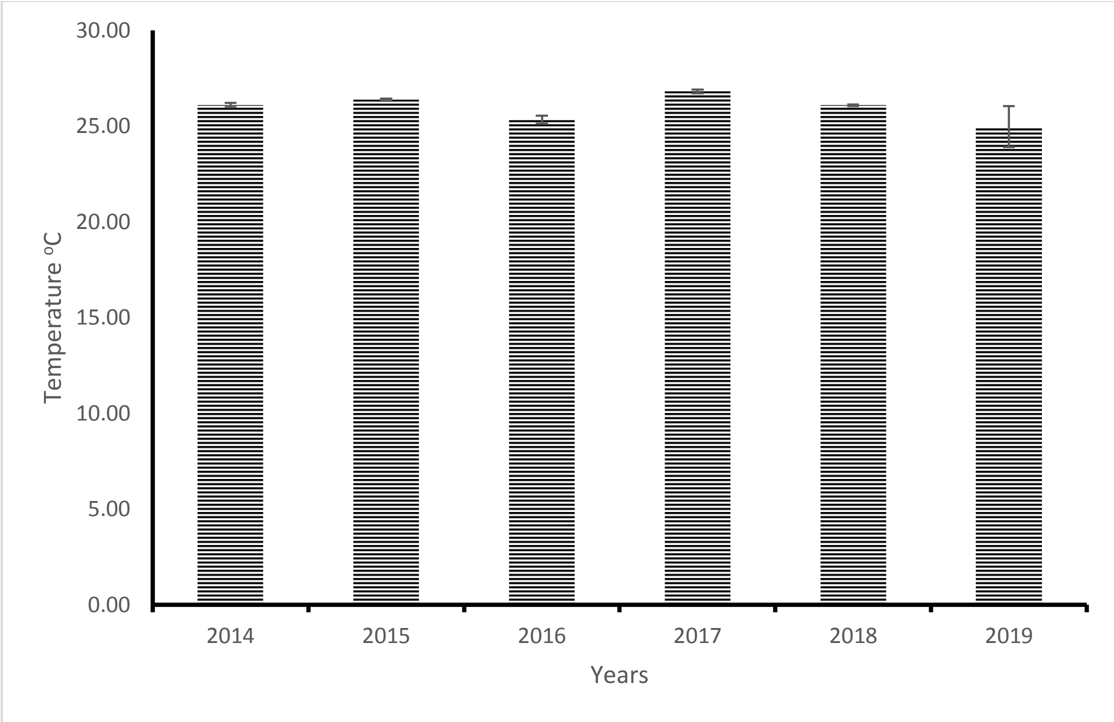

Figure 4-5: (TºC) (± SE) at different sampling period of 2014-19 on UVN

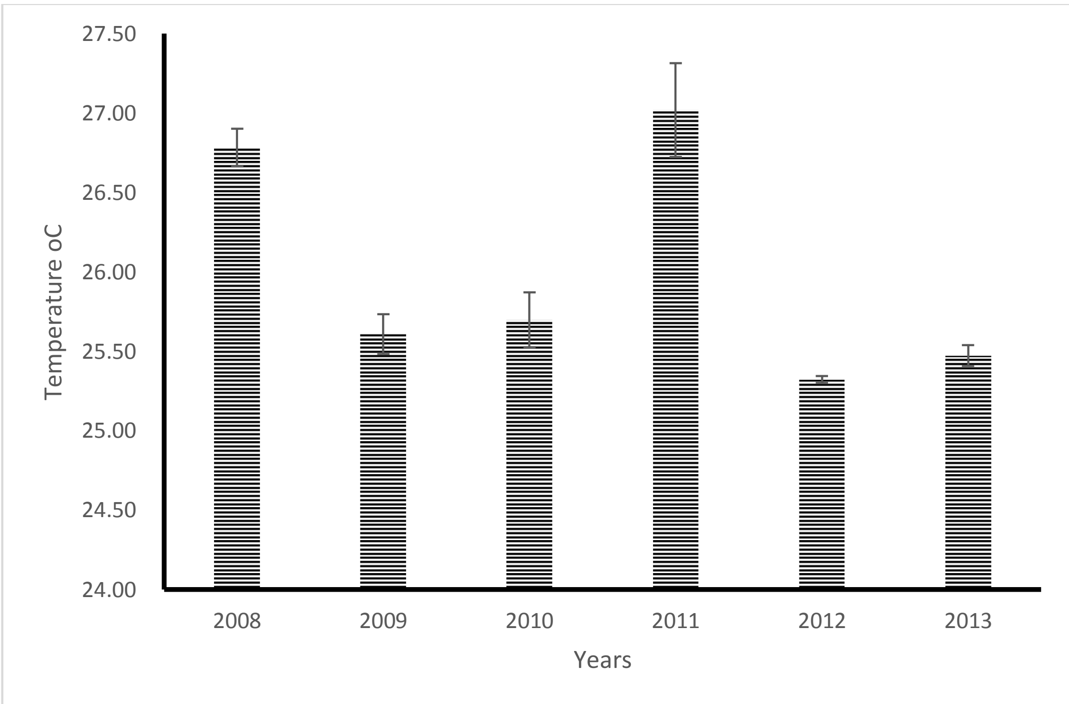

Figure 4-6: (TºC) (± SE) at different sampling periods of 2008-13 on UVN

After combining all the datasets, the Turkey test recorded that 2018 varied with 2010 and 2018 varied with 2013 with lower values of 0.012 and upper values of 0.021 respectively.

4.1.4Dissolved Oxygen (mg/l) variations

The lowest mean DO value (5.86 ± 0.43mgL^{-1}) was recorded at (ST4) whereas the highest value (6.53 ± 1.04mgL$^{-1)}$) was recorded at (ST3). The mean values exhibited a little fluctuation trend downstream (Figure 4-7).ANOVA revealed that there was significant variation between stations (F=2.039; df =107; p=0.049). Turkey test showed that ST8 had a low DO concentration compared to ST5 with a lower difference value of 0.04 and the upper difference value of 1.07.

The lowest mean DO concentration of 4.82 ± 0.11 mgL^{-1} was in 2018 while 2016 recorded the highest mean value (6.47 ± 0.17 mgL^{-1}). The mean generally had a decreasing trend with time and space (Fig.4-8).The sampled years exhibited a significant difference of (F=14.962; df =38; p=0.000).

The results were compared with results from 2008 to 2013 that indicated that DO range from 6.86±0.21 to 7.78±0.030 (Figure 4-9).

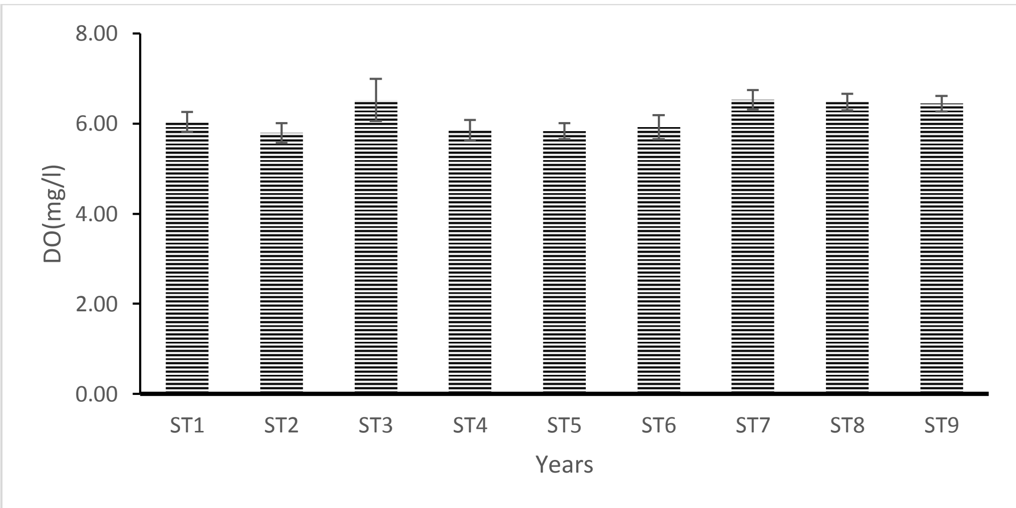

Figure 4-7: DO (mg/L) (± SE) at different sampling stations on UVN

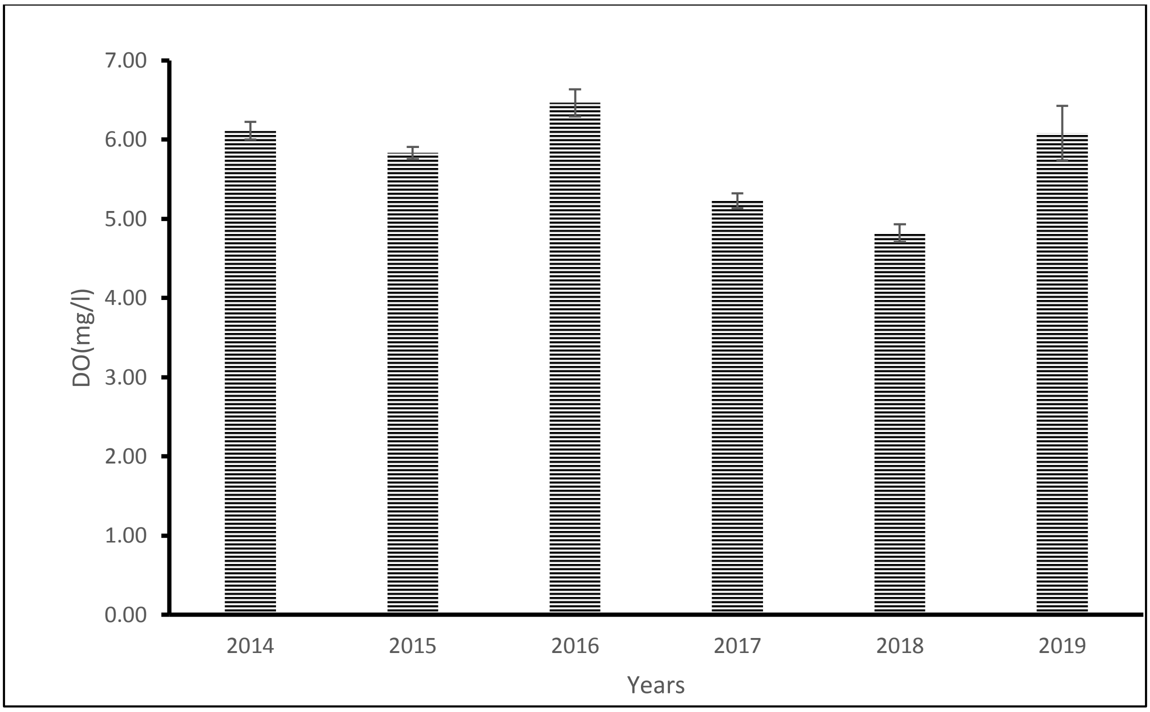

Figure 4-8: DO (mg/L) from UVN (2014-19) on UVN

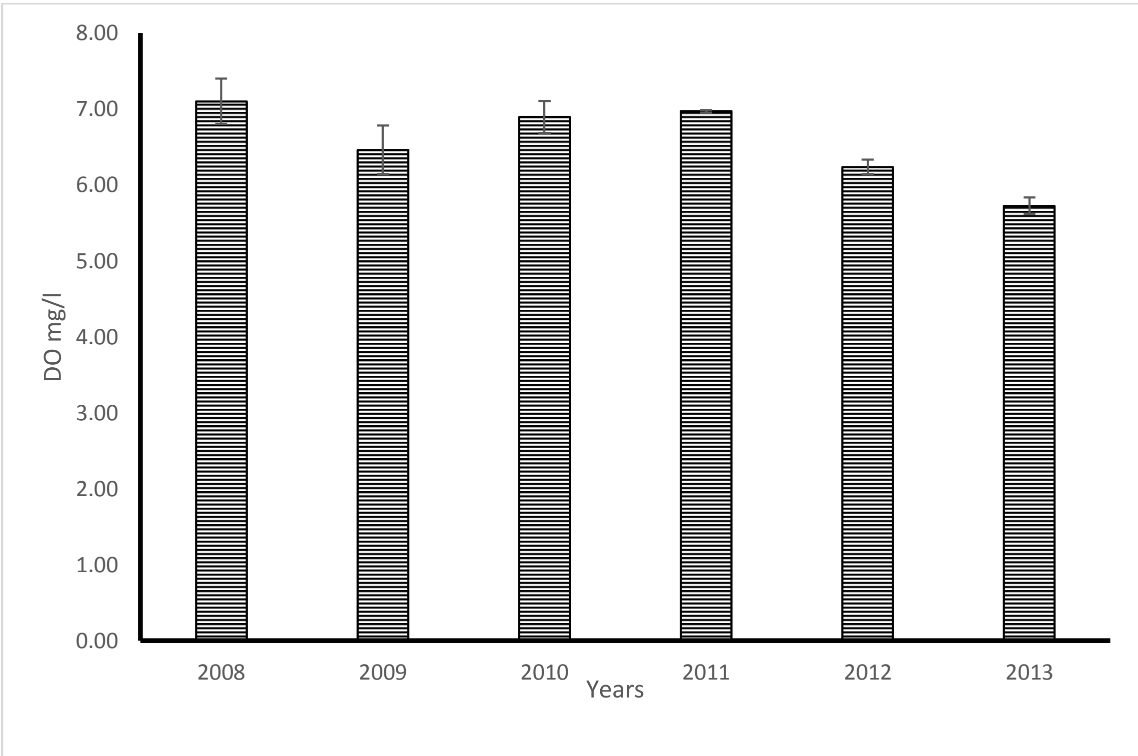

Figure 4-9: DO (mg/L) from UVN (2008-13) on UVN

Turkey test for all combined datasets, recorded that 2017 varied with 2010 and 2018 varied with 2010 with upper values of 0.0199525 and lower values of 0.0038407 respectively.

4.1.5Electrical conductivity (µScm-1)of water in UVN

The lowest mean value (89.56±4.75 μScm^{-1}) of electrical conductivity was recorded at (ST3) whereas the highest (106.44±1.62 μScm^{-1}) was recorded at (ST9). There was a general increasing trend in mean electrical conductivity downstream (Fig. 4-10).

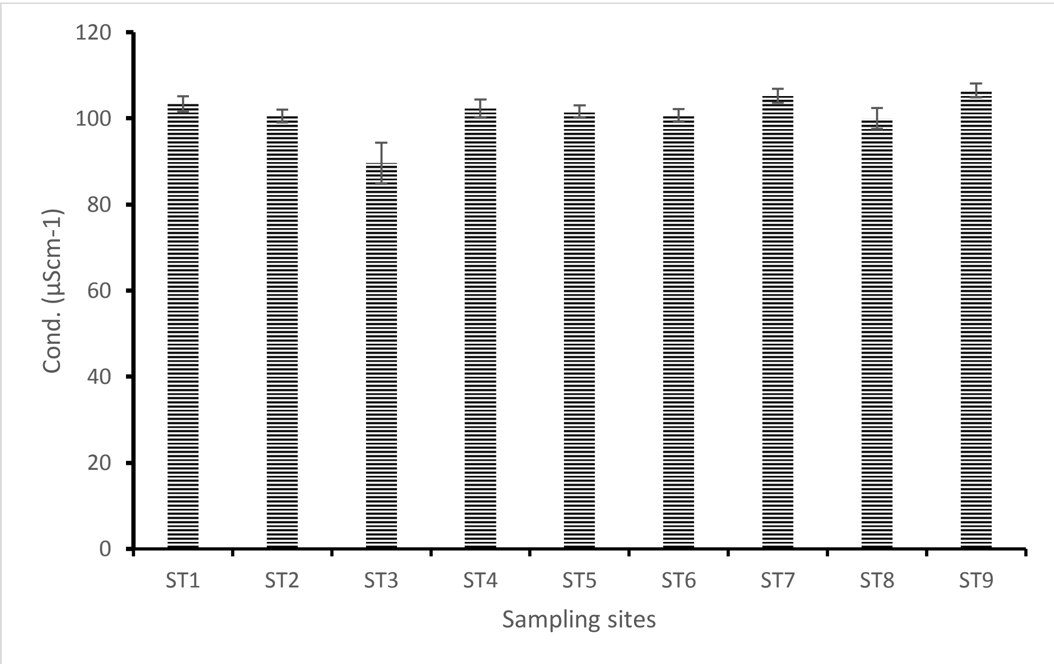

Figure 4-10: Electrical Conductivity (µScm-1) (± SE) at different sampling stations on UVN

ANOVA revealed that conductivity varied significantly (F=3.512; df =107; p=0.001) on a spatial scale of the UVN.Further analysis using the Turkey test revealed that ST7 station had a higher significant variation than ST4 and ST6 by 39.670 and 38.428 on the lower case, while on the upper case, it had differences of 10.663 and 9.248, respectively. ST8 also varied significantly, with ST4 having a higher conductivity level with a lower difference value of -

3.999 and upper difference value of -37.494. ST3 station recorded a low conductivity than ST9 with a lower and upper difference of -58.44 and 32.00, respectively. OnTemporal scale, the mean electrical conductivity varied from 98.62 ± 0.42 μScm^{-1}in 2015 to 103.66 ± 1.29 μScm^{-1} in2016 thesampled period (Fig. 4-11). There was a significant difference in mean electrical conductivity in the sampling period (F=4.811; df = 43; p=0.002).

Findings from the study were compared with results from 2008 to 2013 which indicated that Conductivity ranged from 82.27±0.03 to 114.38±1.13 (Figure 4-12).

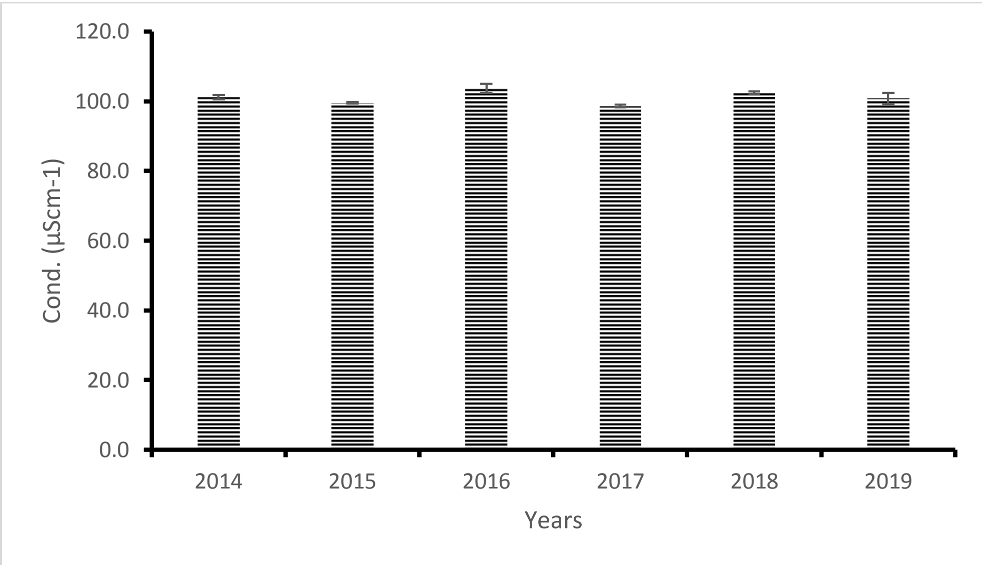

Figure 4-11:Cond. (µScm-1) (± SE) at different sampling period (2014-19) on UVN

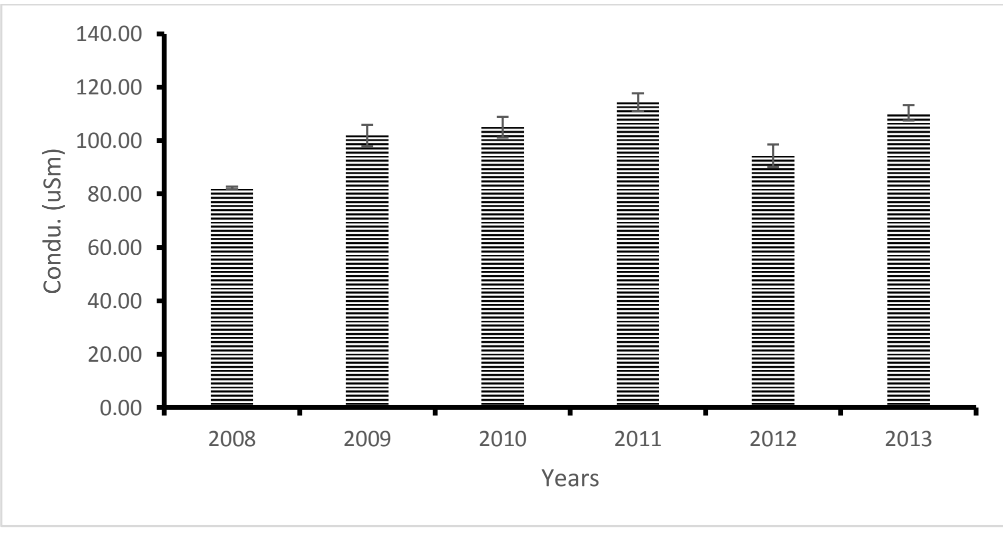

Figure 4-12:Cond. (µScm-1) (± SE) at different sampling period (2008-13) on UVN

Combined datasets, showed that Turkey test recorded lower values in the years of 2012of 0.000 and highest value in 2019 of 0.001respectively (Appendix 14).

4.1.6Total suspended solids (TSS mg/L)

The lowest mean TSSwas recorded at ST1 at 3.07±0.23 mg/l while the highest mean value at ST9 4.25±0.15 mgL^{-1}. The means exhibited a general increasing trend downstream (Figure4-13). There was a statistical significance (F=3.326; df =107; p=0.002) between the stations sampled.

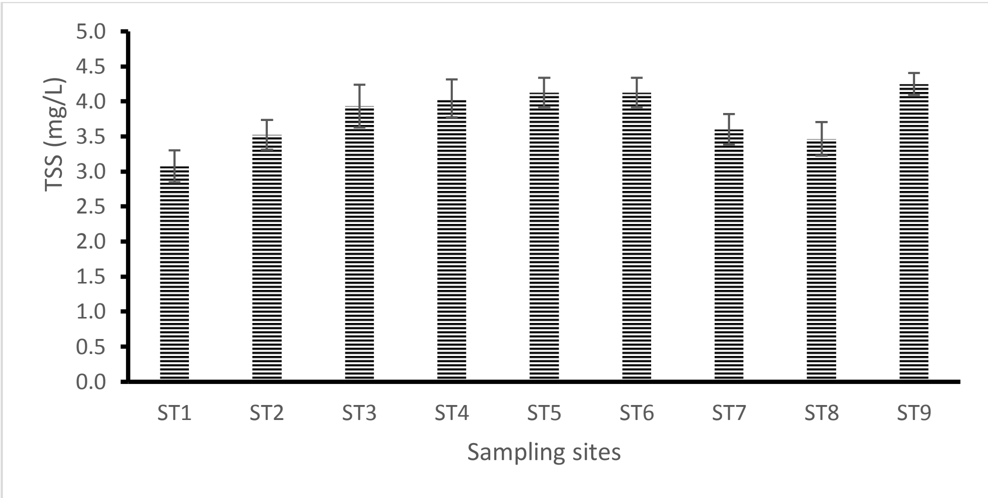

Figure 4-13: TSS mg/L (± SE) at different sampling stations

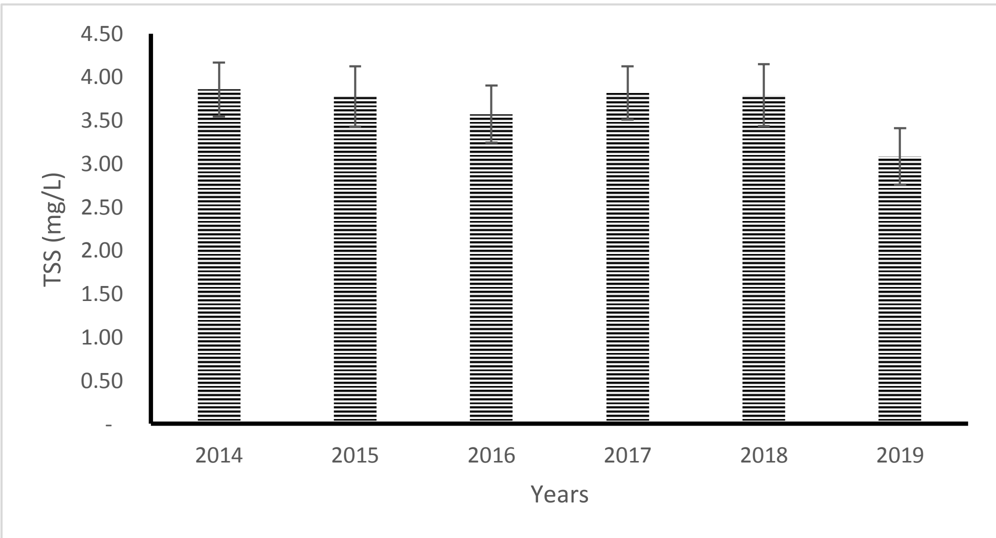

Figure 4-14: TSS mg/L (± SE) at different sampling periods (2014-19)

On spatial scale, the mean Total suspended solids (TSS) ranged from 3.08 ± 0.33mg L^{-1} to 3.86± 0.31 mg $L^{-1}$from 2014-2019 (Figure 4-14).There was a statistically significant variation (F=5.933; df=; 107; p=0.672) between the stations sampled.A detailed analysis using the Tukey test recorded that ST8 varied significantly with ST1 whereby the lower difference recorded was 0.343 while the upper difference was 2.426, respectively. Then, combined datasets showed 2016 and 2015 with lower values of 0.0002386 and upper values of years 2015 and 2009, 2018 and 2009 with values of 0.0403794 and 0.0351922 respectively. The study was compared with results from 2008 to 2013 that indicated that TSS mg/L rangedfrom 3.57±0.93 to 4.42±0.00 mg/l (Figure 4-15).

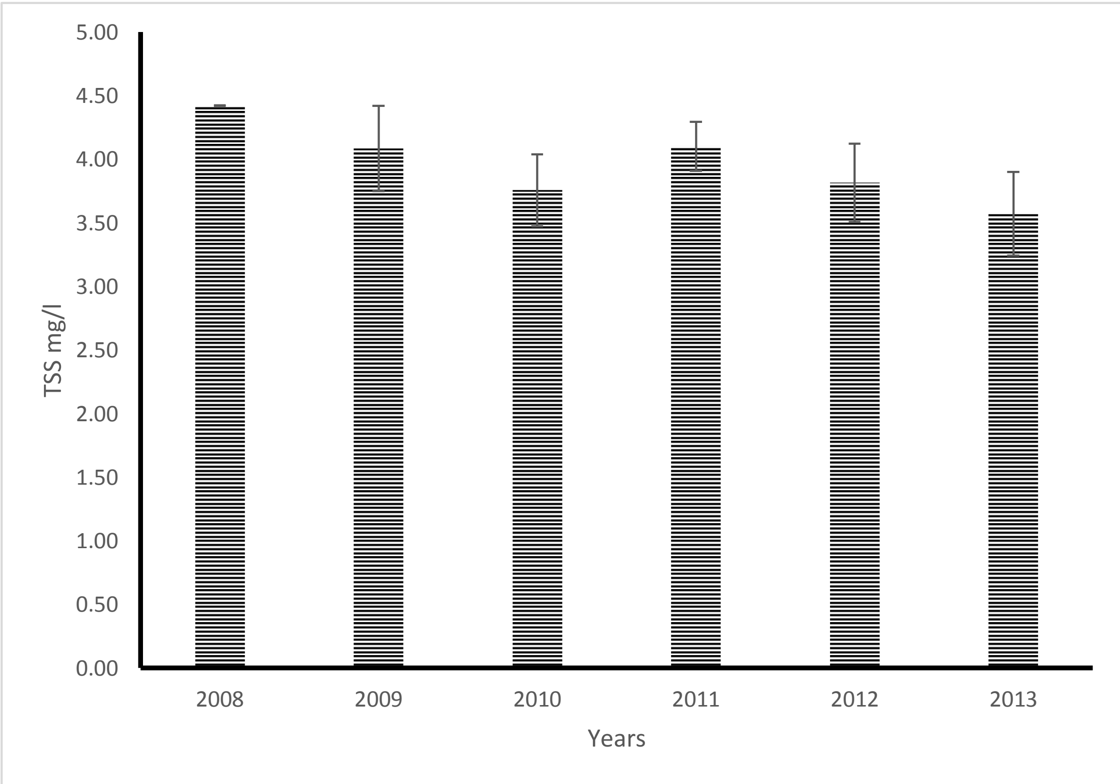

Figure 4-15: TSS mg/L (± SE) at different sampling periods (2008-13)

4.1.7Total Nitrogen concentration TN (µg/L)

The mean total nitrogen concentration TN (µg/L)ranged from 478.58± 91.64 µgL^{-1} at (ST2)and the highest 2,020±725.32 µgL^{-1} at(ST3) (Figure 4-16).There was a significant difference realized between sampled stations with ($F=3.988$; df = 107 $p=0.000$). On temporal scale, the lowest mean TN (390.67 ± 99.27 µgL^{-1}) was recorded in 2019and the highest mean (1,205.53±202.65 µgL^{-1}) was recorded in 2014. The means exhibited a general decreasing trend from2014 to 2019 (Figure 4-17).

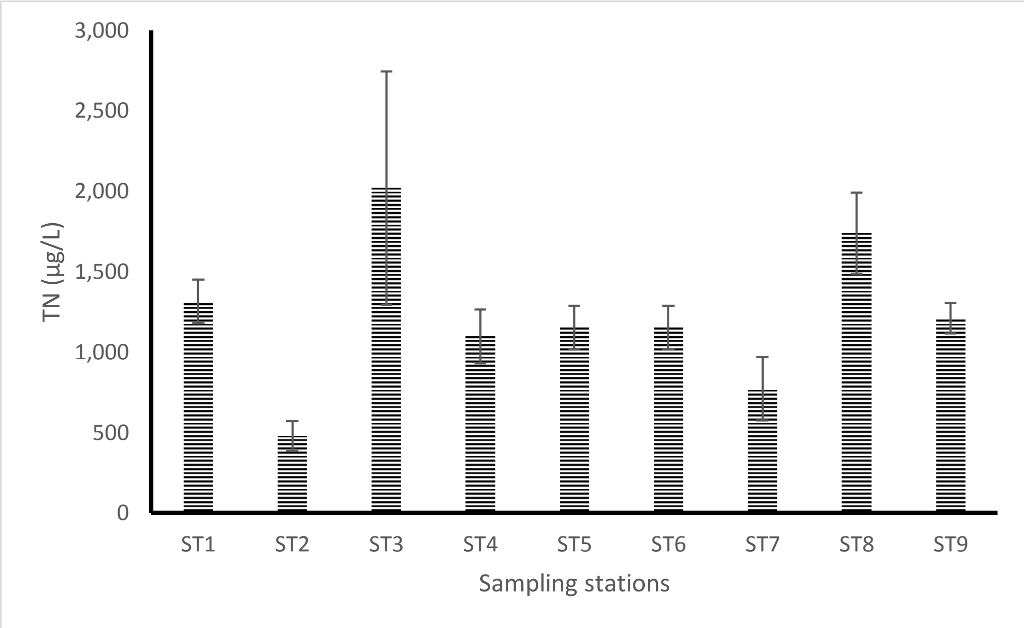

Figure 4-16: TN (µg/L) (± SE) at different sampling stations

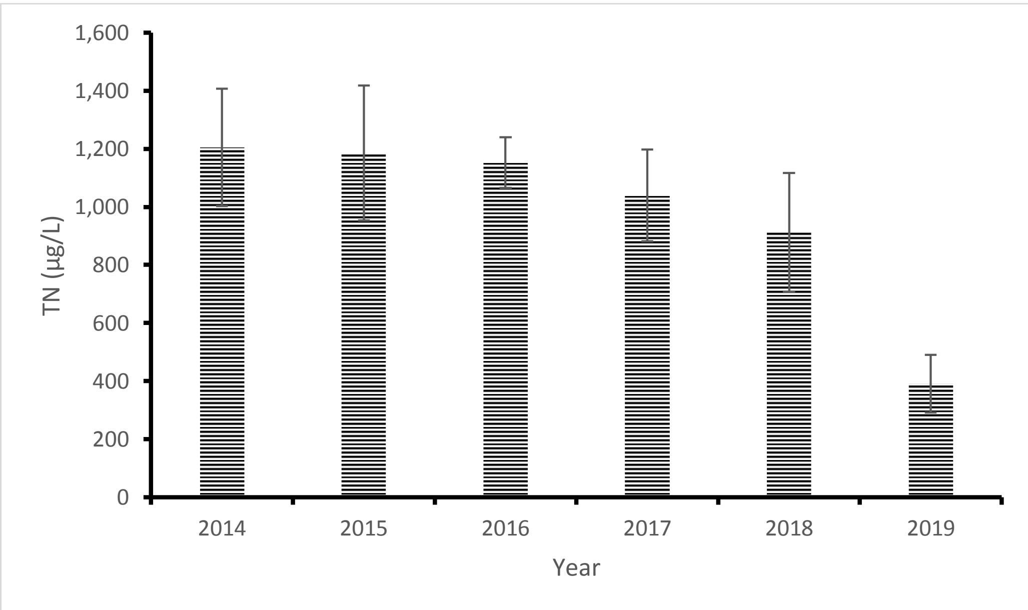

Figure 4-17: TN (µg/L) (± SE) at different sampling periods (2014-19)

Total nitrogen concentration (TN) was significant with (F= 2.747;df = 43; p=0.033) for the sampling period. The study was compared with results from 2008 to 2013 that indicated that Total nitrogen concentration (TN) rangedfrom1205.53±205.65 to 3328.25±425.65 (µg/L) (Figure 4-18).

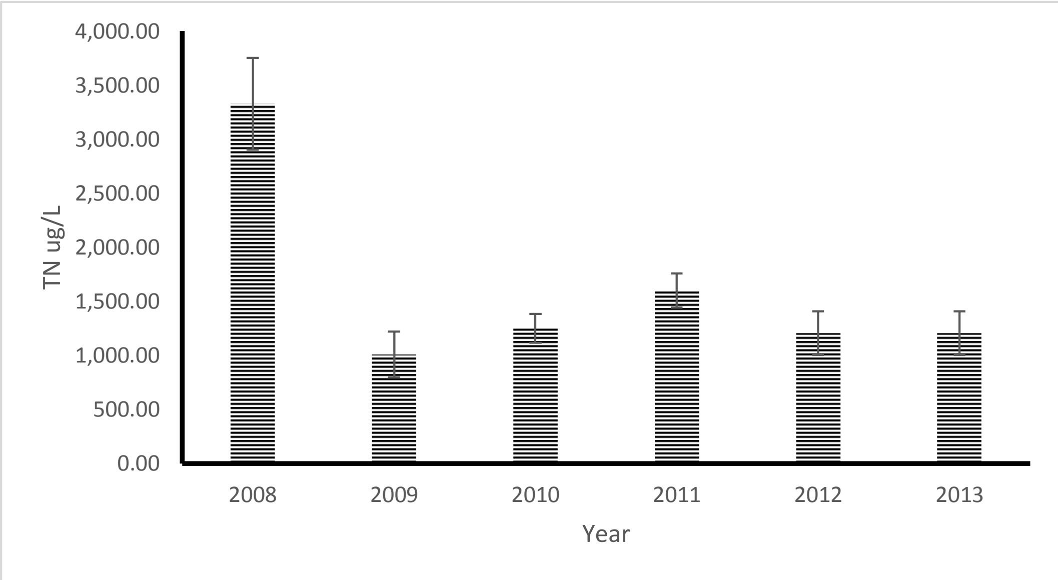

Figure 4-18: TN (µg/L) (± SE) at different sampling periods (2014-19)

After combining all the datasets, the Turkey test recorded that 2017 varied with 2008 and 2010 varied with 2008. 2011 varied with 2008 with lower values of -3458.728, -2663.518, -3135.01 and upper values of -1373.146, -789.165, -110.484, respectively.

4.1.8Total Phosphorous TP (µg/L) concentration variation

On the spatial scale, the mean Total phosphorous ranged from 53.3 ±0.87µgL^{-1} at (ST5) to 80.75±15.43µgL^{-1} at (ST2). The mean values indicated a fluctuation trend downstream of the river (Figure 4-19).The mean Total Phosphorus (TP) values had no a significant difference (F=1.248; df=107; p=0.280) between the sampled stations. Turkey test recorded no significant variation between stations.

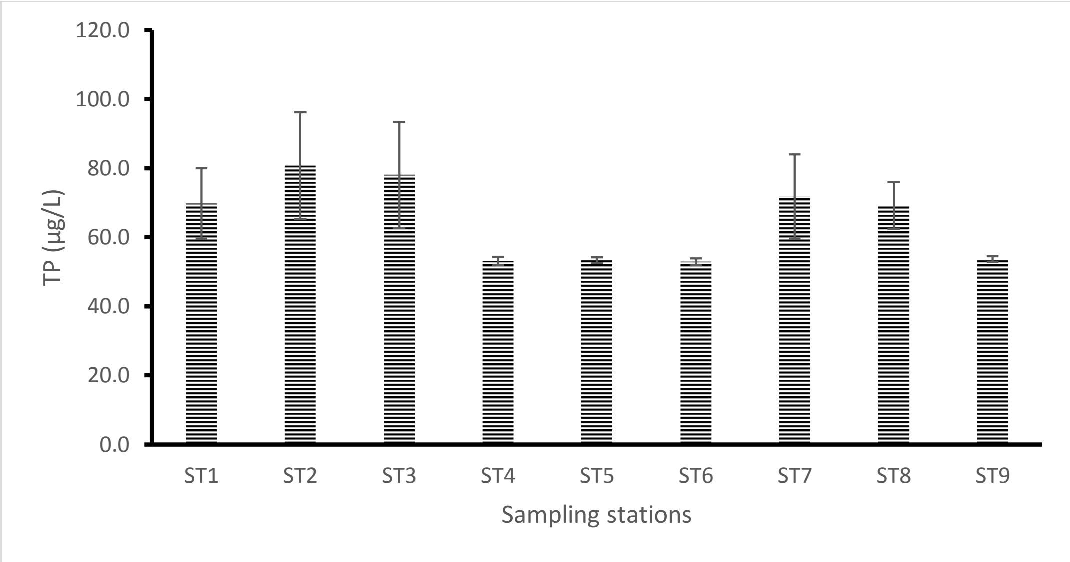

Figure 4-19: TP (µg/L) (± SE) at different sampling stations

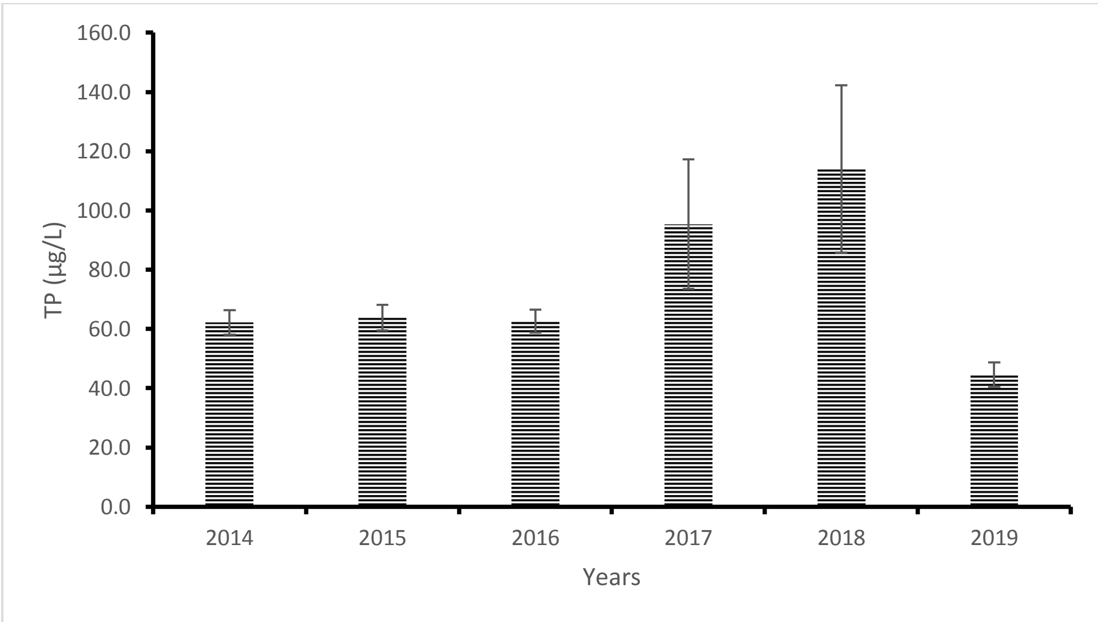

Figure 4-20: TP(µg/L) (± SE) at different sampling periods (2014-19).

On temporal scale, 2019 exhibited the lowest mean TP concentration of 43.58 ±4.07 µgL^{-1} while 2018 had the highest mean value of 113.96 ± 28.22µgL^{-1}(Figure 4-20).ANOVA revealed a significant variation (F=2.750; df= 43; p=0.032). The study was compared with results from 2008 to 2013 that indicated that TP concentration (TN) rangedfrom50.51±3.79 to 103.0±13.59 (µg/L) (Figure 4-21).

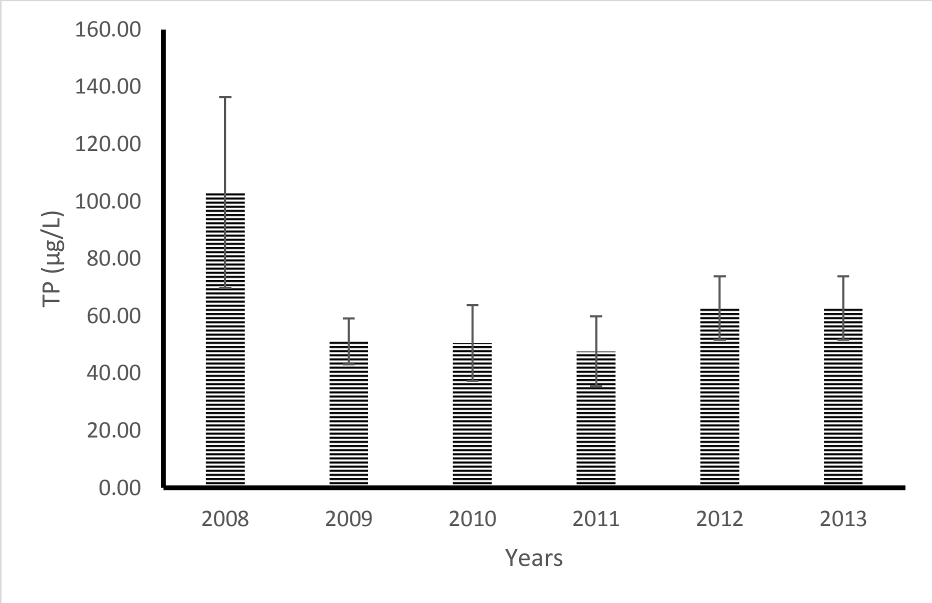

Figure 4-21: TP (µg/L) (± SE) at different sampling periods

4.1.9Secchi Depth (M) variations

On spatial scale, the total mean Secchi depth varied with sampling stations; 1.44± 0.08 at ST9and the highest at ST3with a value of 1.94±0.07 meters with ($F=1.597$; $df=107$; $p=0.135$) (Figure 4-22). On temporal scale there were fluctuations in the Secchi depth which increased with time and recorded significant difference of ($F=12.942$; $df=43$; $p=0.000$) (Fig.4-23).

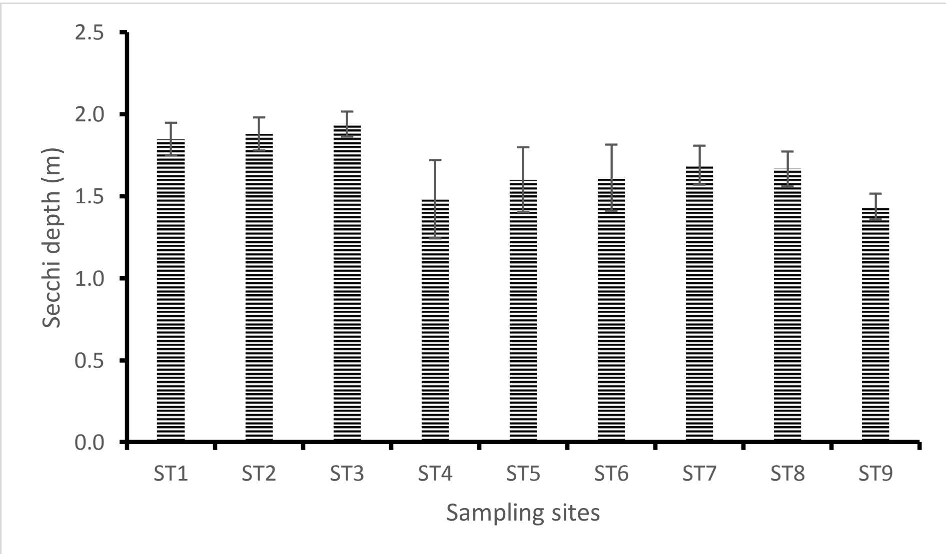

Figure 4-22: Secchi depths (m) (± SE) at different sampling stations

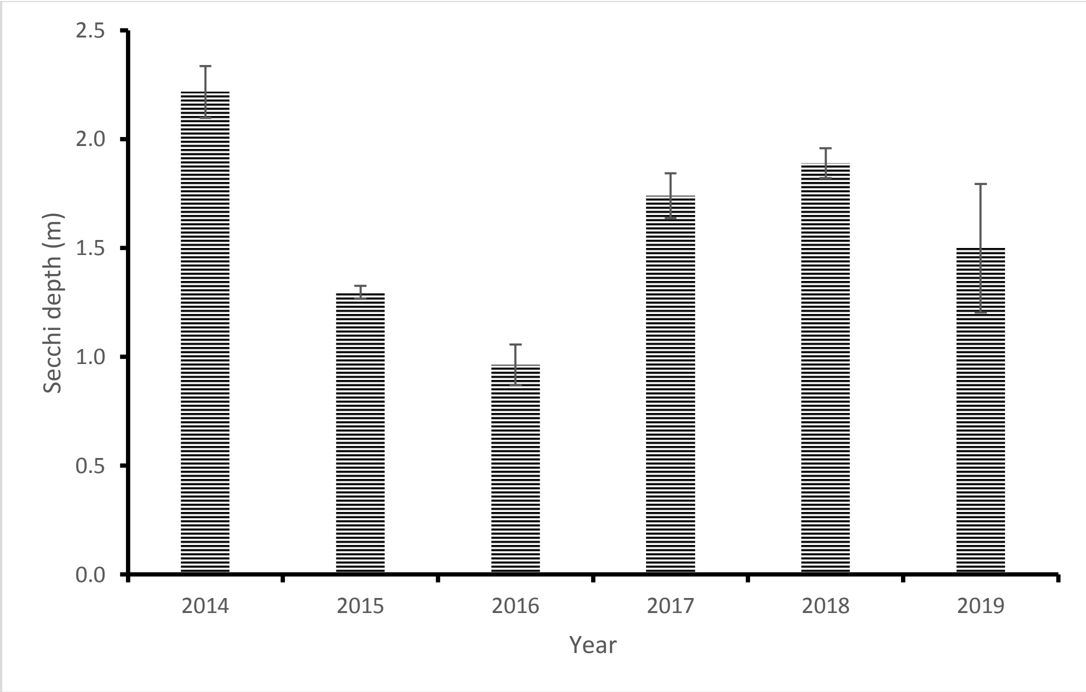

Figure 4-23: Mean Secchi depth SD (± SE) for the sampled UVN (2014-19)

The study was compared with results from 2008 to 2013 that indicated that SD (m) concentration (Mean Secchi depth) ranged from1.60±0.08 to 1.98±0.10 (µg/L) (Figure 4-4-24).

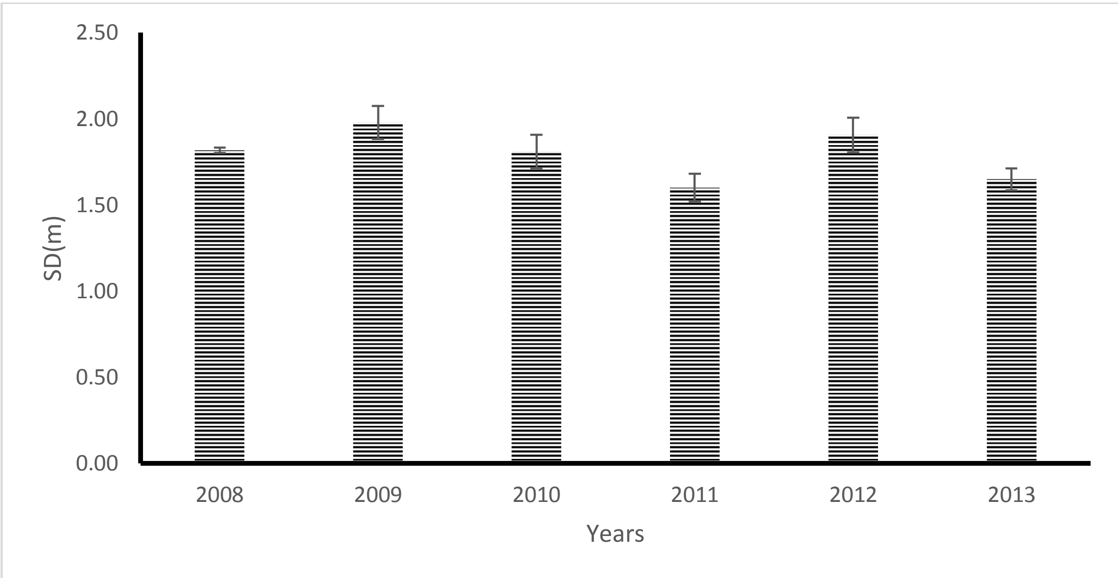

Figure 4-24: Mean Secchi depth SD (± SE) for the sampled UVN (2008-13)

4.1.10Ammonia NH4-N (ug/L) variations

On spatial scale, the mean Ammonia ranged from 2.07 ±0.05µgL^{-1} at (ST1)to3.83±0.34µgL^{-1} at ST5. The mean values indicated a fluctuation trend downstream of the river (Figure 4-25).

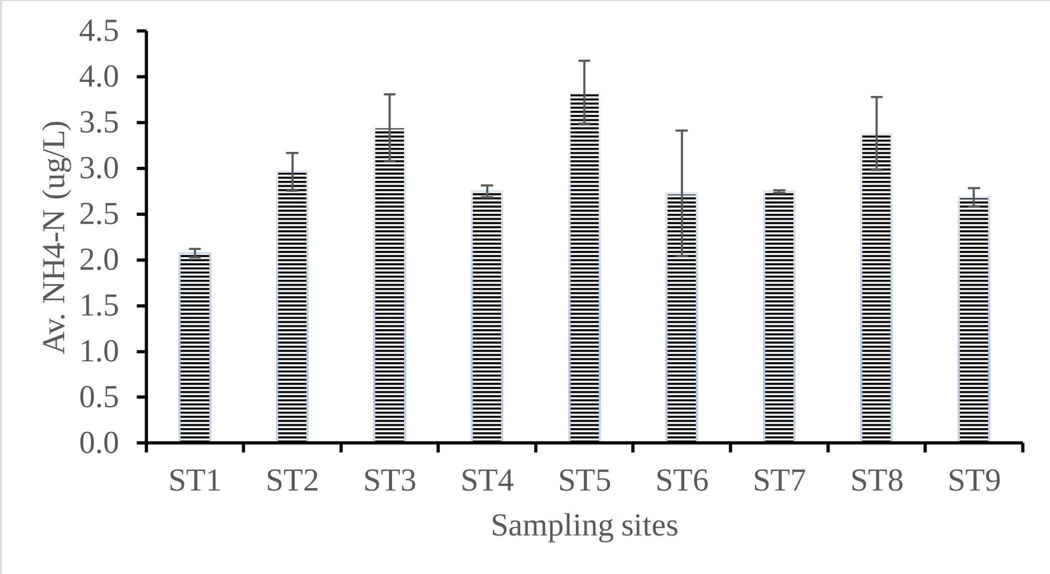

Figure 4-25: Mean NH4-N (ug/L) (± SE) from different sampling stations.

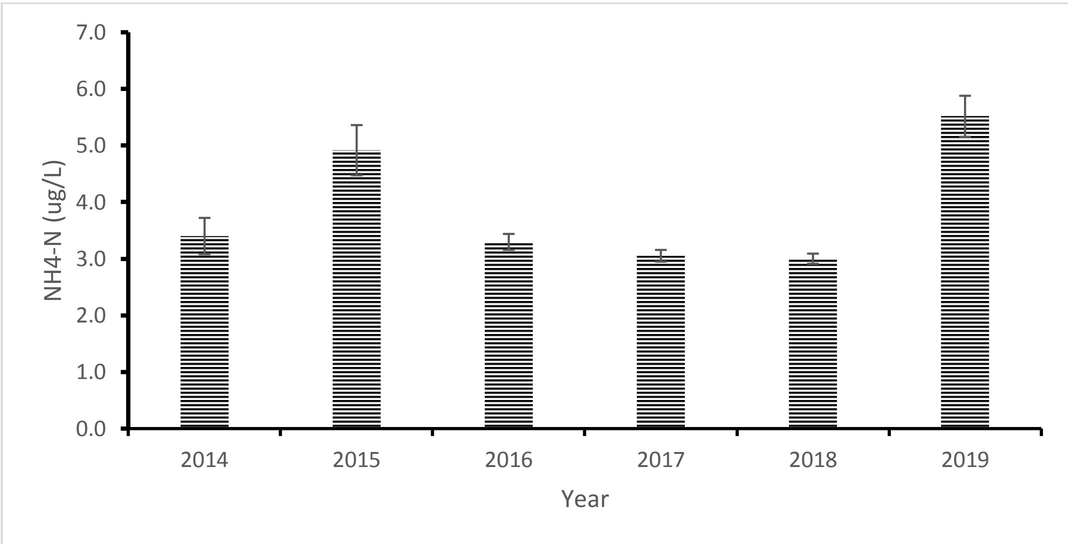

Figure 4-26: Mean NH4-N (ug/L) (± SE) for different periods (2014-19).

The mean Ammonia (NH4-N (ug/L) values were not significantly different (F=0.884; df = 107; p=0.533) between sampled stations. The Post hoc test (Turkey test) recorded a significant variation between ST1 and ST5 stations with a lower value of -3.411 and an upper value of -0.048.

On temporal scale, 2018 exhibited the lowest mean Ammonia concentration of 3.00± 0.65µgL^{-1} while 2019had the highest mean value of 5.52±0.36µgL^{-1}. The means showed a fluctuation trend from 2014 to 2019 (Figure 4-26).ANOVA showed a significant variation ($F=113.089$; df = 43; $p=0.000$) for the sampled time.

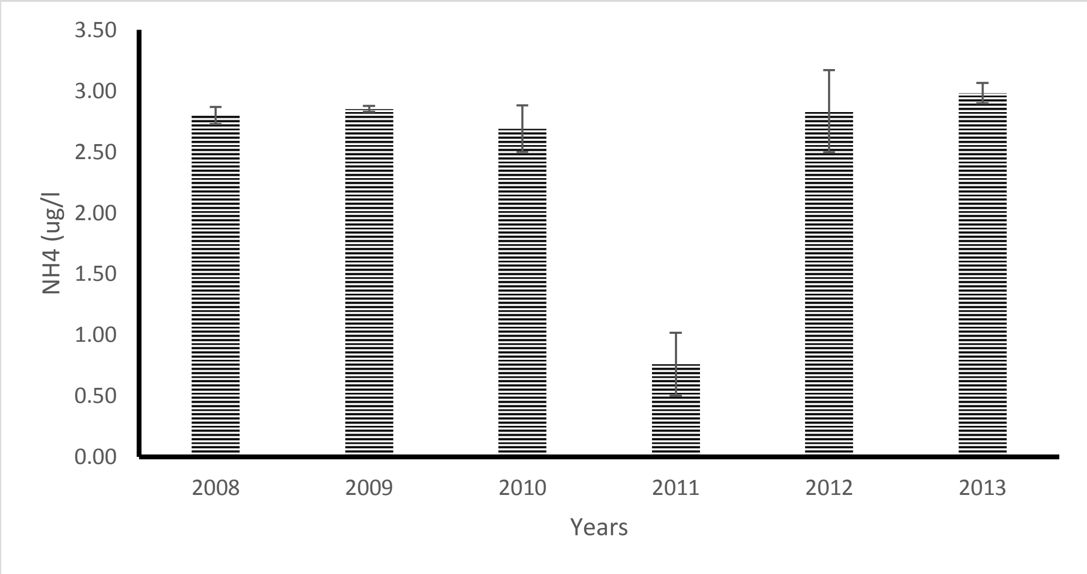

Figure 4-27: Mean NH4-N (ug/L) (± SE) for different periods (2008-13)

The study was compared with results from 2008 to 2013 that showed that NH4-N (ug/L) concentration ranged from0.76±0.02 to 2.85±0.34 (µg/L) (Figure **4-27).**After combining all the datasets, the Turkey test recorded that 2012 varied with 2016 varied with 2008, 2017 varied with 2008, 2010 varied with 2009 as observed in the appendices.

4.1.11NO3-N (µg/L) Concentrations

The mean NitrateNO3-N (µg/L) concentrations ranged from 62.27±3.79 μgL^{-1} at(ST1) to 142.53±11.58μgL^{-1} at (ST2). The mean values indicated a decreasing trend downstream of the river (Figure 4-28).The mean NO3-N (µg/L) values were significant with ($F=4.513$; df = 107; $p=0.000$) between sampled stations.

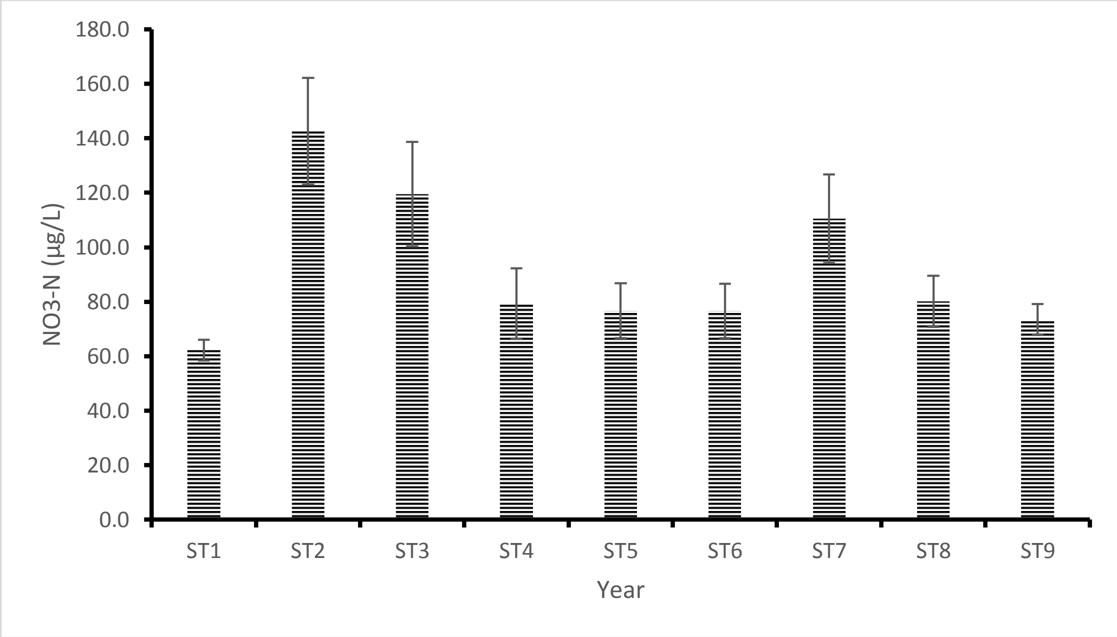

Figure 4-28: Mean NO3-N concentrations (µg/L) (± SE) for different sampled stations

On temporal scale, 2017 exhibited the lowest mean Nitrate concentration of 61.19 ± 2.27µgL^{-1} while 2019 had the highest mean value 101.95±20.45µgL^{-1}. The means showed a slight decreasing trend from 2014 to 2019 (Figure 4-29). ANOVA recorded no significant variation (F=1.164; df=107; p=0.345) for the sampled period. The Post hoc test (Turkey test) recorded a no significant difference between ST3 and ST5, ST9, ST8, ST3, ST1, ST7 and ST3 with lower values of 28.350, 21.635, 28.250, 30.905, 3.292 and upper values of 147.844, 154.445, 147.744, 128.650, and 96.685, respectively. The study was compared with results from 2008 to 2013 that showed that NO3-N (µg/L) concentration ranged from 0.76±0.02 to 2.85±0.34 (µg/L) (Figure 4-30). Then Tukey test for the combined datasets showed 2014 varied with 2012, 2016 varied with 2014 and 2018 varied with 2014 with 0.04012109, 0.02231115 and 0.0258800 respectively.

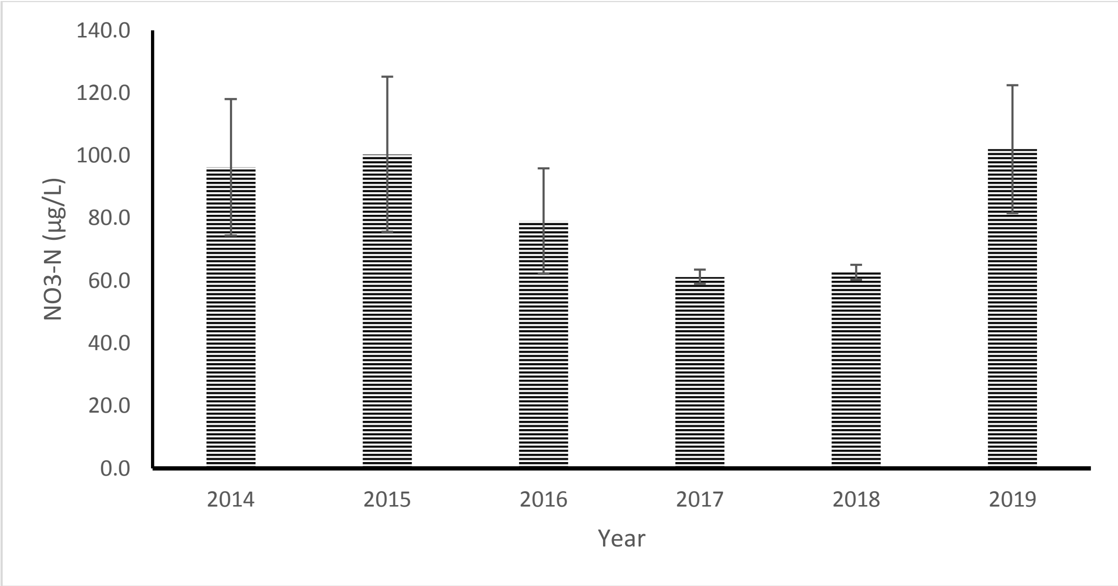

Figure 4-29: Mean NO3-N (µg/L) (± SE) for different sampling period (2014-19)

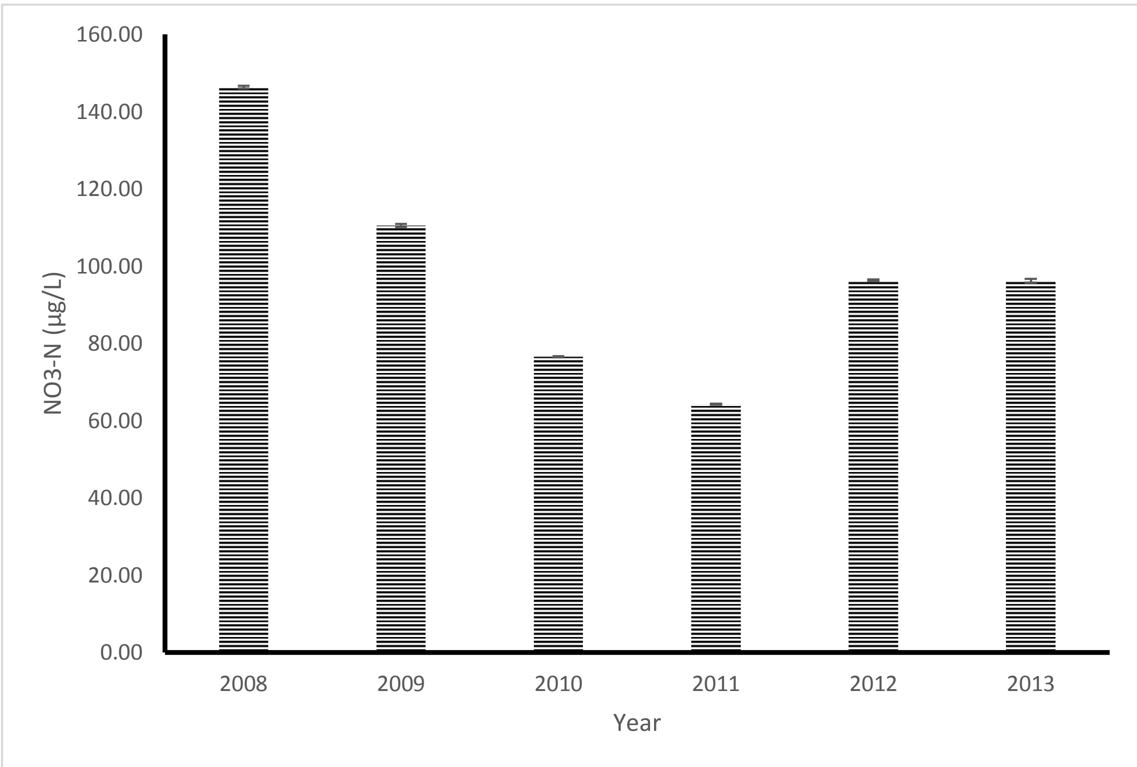

Figure 4-30: Mean NO3-N (µg/L) (± SE) for different sampling period (2008-13)

4.1.12PO4-P (µg/L) Concentrations

The mean Phosphate PO4-P (µg/L) concentrations ranged from 13.54±0.95µgL^{-1} at (ST9) to 17.39±1.17µgL^{-1} at (ST1). The mean values indicated a decreasing trend downstream of the river (Figure 4-31). The mean PO4-P (µg/L) values were not a significantly different (F=0.449; df = 43; p=0.396) between sampled stations

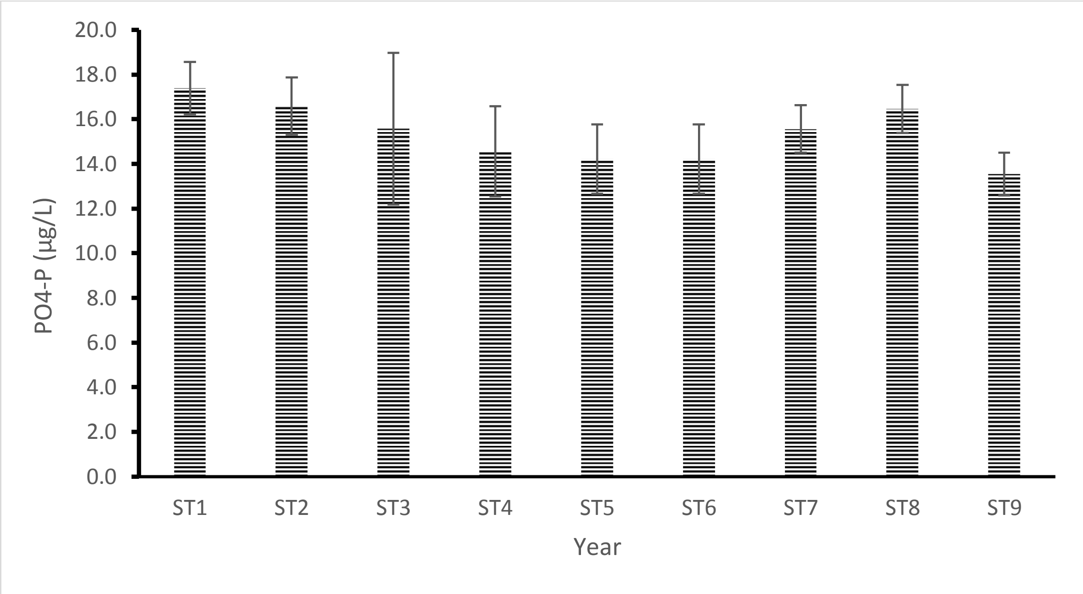

Figure 4-31: Mean PO4-P (µg/L) (± SE) for different sampled stations.

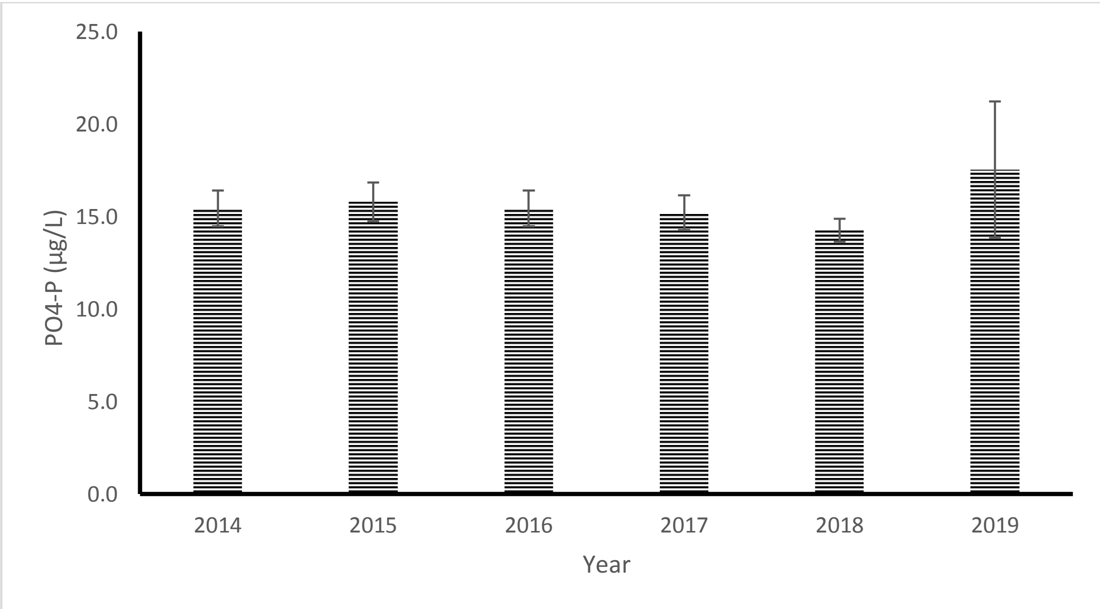

Figure 4-32:MeanPO4-P (µg/L) (± SE) for different sampled stations (2013-19).

On temporal scale, 2018 exhibited the lowest mean Phosphate concentration of 14.27 ± 0.61μgL^{-1} while 2019 had the highest mean value 17.55±3.68 μgL^{-1}. The means recorded a slight increase trend from 2014 to 2019 (Figure 4-32). ANOVA recorded no significance (F=1.061; df= 107; p=0.812) for the temporal scale. The Post hoc test (Turkey test) recorded significant variation between ST6 and ST5, ST2 exhibited lower values of 2.309, 2.309 and upper values of 23.891, 23.891 respectively. ST8 varied with ST5 and ST3 with ST7 with lower values of -24.520, -0.617 and upper values -1680, -11.858 respectively. The study was compared with results from 2008 to 2013 that showed that PO4-P (μg/L) concentration ranged from 12.28±5.50 to 29.70±0.97 (μg/L) (Figure 4-33).

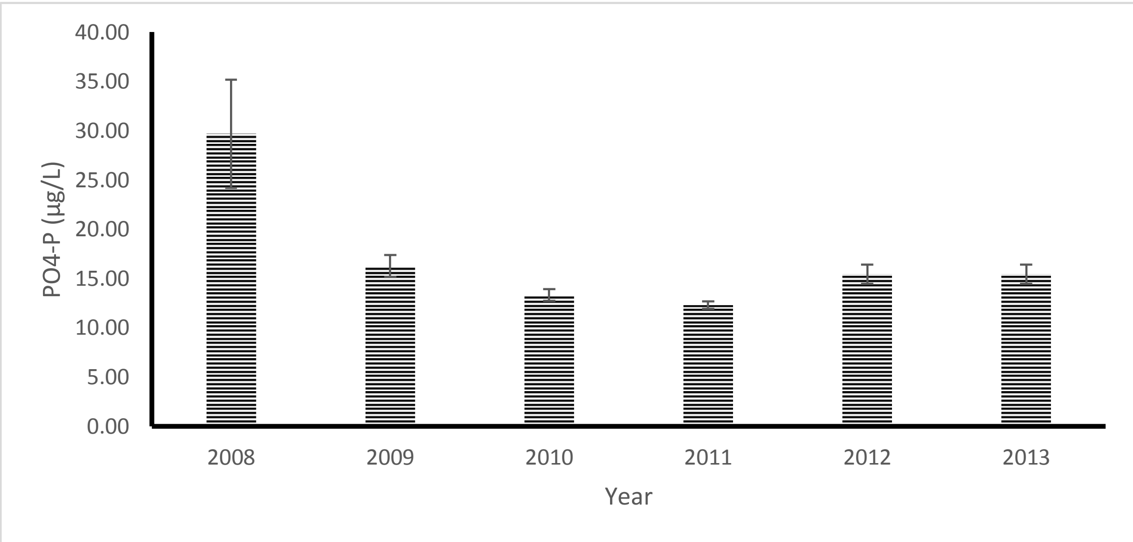

Figure 4-33: Mean PO4-P (μg/L) (± SE) for different sampled stations (2008-13)

4.1.13Principal Component Analysis (PCA) for Water Parameters

Principal Component Analysis (PCA) ordination of environmental variables reflected variations along the sampled sites along the river section. The first, second and third axes accounted for 20.6%, 14.5% and 12.0% of the total variance among the sampled sites (Figure 4-34). The first axis was negatively associated with dissolved oxygen and NO3-N, while the second axis positively correlated with pH and PO4-P.

The permutation multivariate analysis of variance (PERMANOVA) indicated that environmental characteristics differed significantly between sites, upstream. Midstream and downstream (Pseudo-F = 0.97608, P (perm) = 0.459, 0.105, 0.685) but these conditions differed over the years Pseudo-F = 2.5998, P (perm) = 0.001). There was no significant difference resulting from the interaction between annual sampling for the sampled sites along the river section (Pseudo-F = 0.46916, P (perm) = 1). Along the gradient in the river section, only the DO showed significant differences across the sampled sites ($p<0.05$, ANOVA). However, over the years, total dissolved oxygen, pH, nutrients (NH_4, NO_2 & TN) were significantly different (Appendix 14).Furthermore, Tukey HSD showed that the differences observed in DO is only due to difference between Upstream – Downstream, and Upstream-Downstream but not Upstream-Midstream (Appendix 12,13).

4.1.14 Habitat Quality Index (HQI) variations

The habitat quality index varied from 23.13±1.23 at (ST7) to 28.00±0.00 at (ST3) (Figure 4-35). The mean habitat quality index exhibited a significant difference (F=3.988; df = 107; p=0.000) between stations for the whole period of samplings. On temporal scale, 2017 exhibited the lowest mean HQI of 19.63 ± 1.41 while 2014 had the highest mean value of 27.00±1.22. The means showed a slight decreasing trend from 2008 to 2018 (Figure 4-36). ANOVA recorded significant variation (F=3.853; df= 43; p=0.006) for the sampled period. The study was compared with results from 2008 to 2013 that showed that HQI concentration ranged from 23.75± 0.71 to 28.33±0.21 (Figure 4-37).

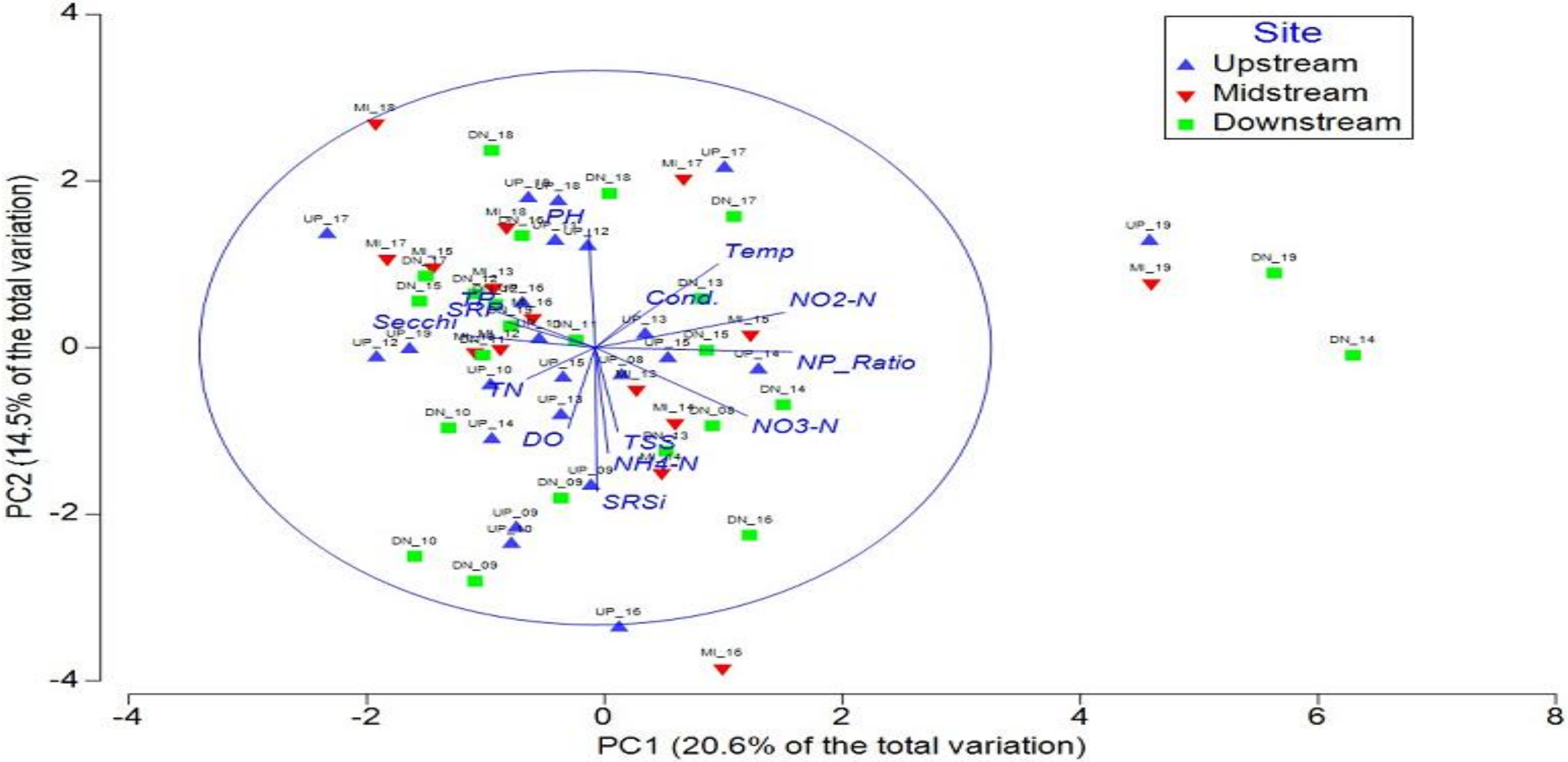

Figure 4-34: Principal Component analysis (PCA) ordination plot based on environmental variables using Euclidean distances amongst the sites along the variables (Combined datasets 2008-19).

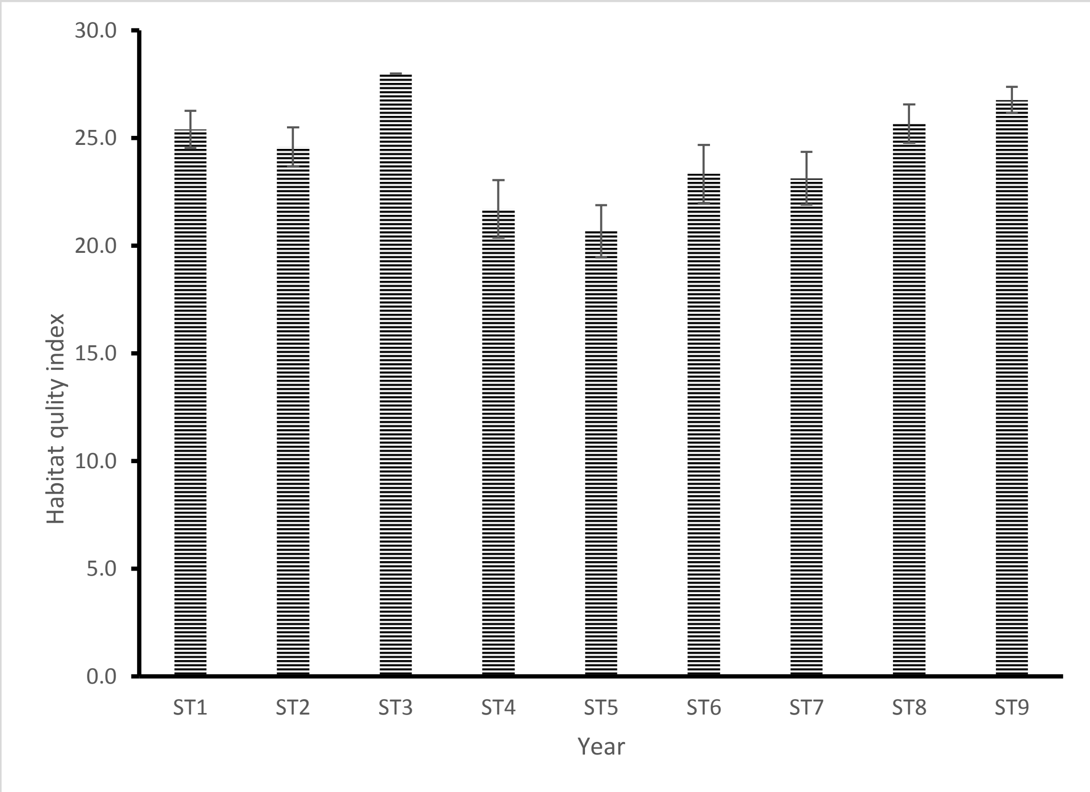

Figure 4-35: Mean HQI values at the different sampling station

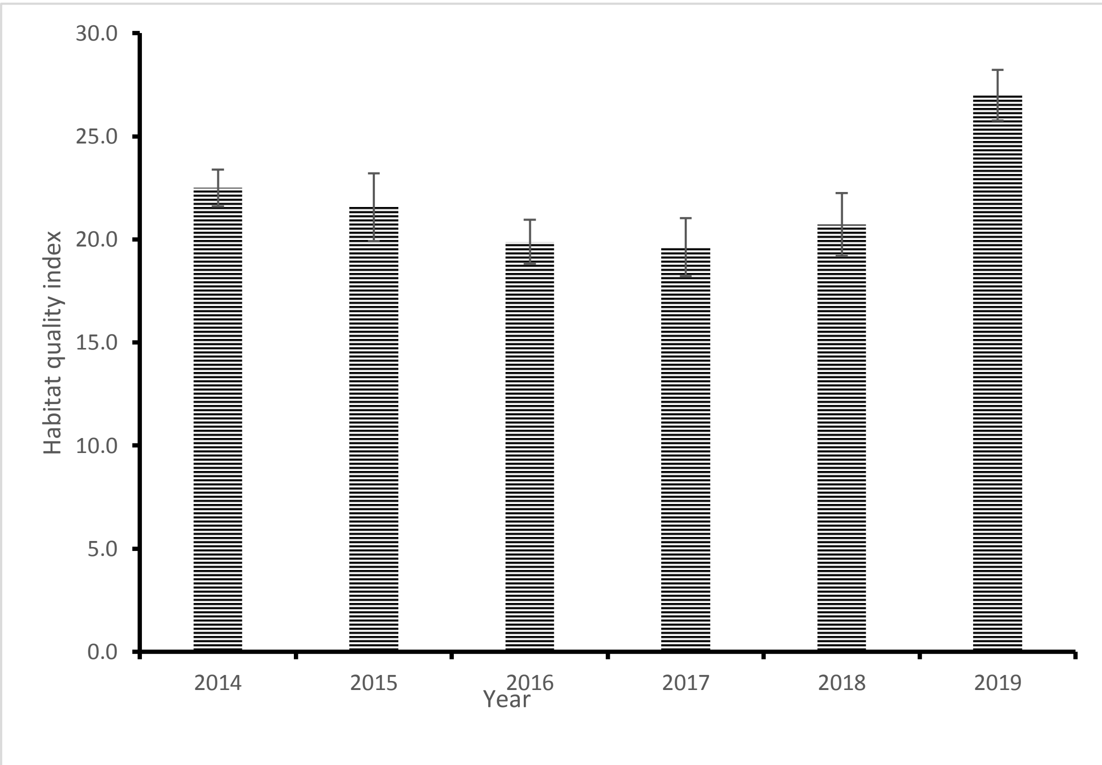

Figure 4-36: Mean HQI (± SE) for different sampled periods (2014-19)

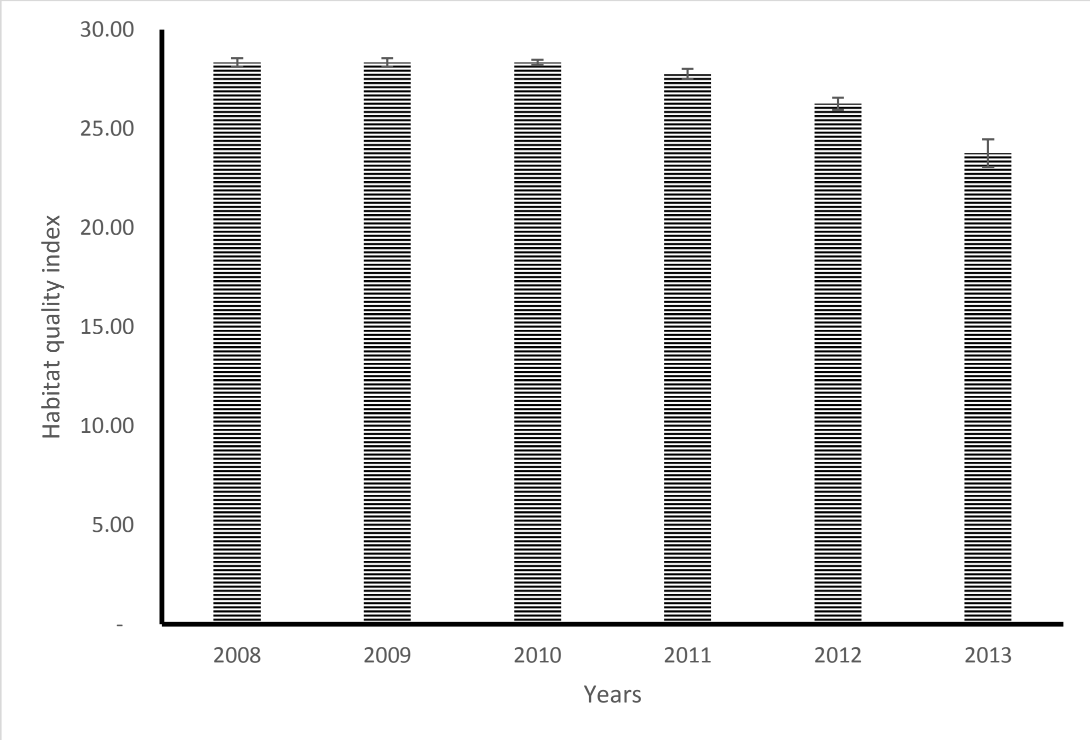

Figure 4-37: Mean HQI (± SE) for different sampled periods (2008-13)

4.2.2 Fish Community Characteristics

4.2.2.1Fish Community Structure

Five thousand two hundred and two (5,202) fish were recorded belonging to 10 families and 67 species from experimental gillnets. Of the species sampled 3 were non-native (exotic) while the remaining were native species.Trophic guild recorded as follows;Carnivores were (22.4%). Omnivores were (62.7%) and detrivores were (14.9%). The families encountered were the Cichlidae (56), Mormyridae (2), Claridae (1), Latidae (1), Mochokidae (2),Polypteridae (1),Bagridae (1), Cyprinidae (2) and Alestidae (1)(Table 4-1).

Table 4-1: Fish species classification as per the taxa, status, tolerance and trophic guild

Family	Species	Status	Tolerance level	Trophic guild
Cichlidae	*Astatochromis pink dorsal*	*native*	*Omnivore*	*Intolerant*
	Astatoreochromis alluaudi	*native*	*Omnivore*	*Intolerant*
	Astatotilapia "red dorsum"	*native*	*Omnivore*	*Intolerant*
	Astatotilapia brownie	*native*	*Omnivore*	*Intolerant*
	Astatotilapia elongate	*native*	*Omnivore*	*Intolerant*
	Astatotilapia nubile	*native*	*Omnivore*	*Intolerant*
	Astatotilapia purple dorsum	*native*	*Omnivore*	*Intolerant*
	Astatotilapia red anal	*native*	*Omnivore*	*Intolerant*
	Astatotilapia scarlet anal fin	*native*	*Carnivore*	*Intolerant*
	Astatotilapia spp	*native*	*Omnivore*	*Intolerant*
	Astatotilapia yellow	*native*	*Omnivore*	*Intolerant*
	Coptodon zilli	*native*	*Omnivore*	*Tolerant*
	Curved head Neochromis	*native*	*Omnivore*	*Intolerant*
	Gaurochromis	*native*	*Carnivore*	*Intolerant*
	Haplochromines	*native*	*Detrivores*	*Tolerant*
	Harpagochromis "shovel mouth"	*native*	*Detrivores*	*Intolerant*
	Harpagochromis guiarti	*native*	*Carnivore*	*Intolerant*
	Lipochromis microdon	*native*	*Carnivore*	*Intolerant*
	Lipochromis pavidens	*native*	*Carnivore*	*Intolerant*
	Lithochromis	*native*	*Omnivore*	*Intolerant*
	Mbipia "blue"	*native*	*Omnivore*	*Intolerant*
	Mbipia mbipi	*native*	*Omnivore*	*Intolerant*
	Mbipia red	*native*	*Omnivore*	*Intolerant*
	Mbipia yellow	*native*	*Omnivore*	*Intolerant*
	Neochromis elongate	*native*	*detrivores*	*Intolerant*
	Neochromis greenwoodi	*native*	*detrivores*	*Intolerant*
	Neochromis nigricans	*native*	*detrivores*	*Intolerant*
	Neochromis rufocaudalis	*native*	*detrivores*	*Intolerant*
	Neochromis thichlips	*native*	*detrivores*	*Intolerant*
	Oreochromis leucostictus	*native*	*detrivores*	*Tolerant*
	Oreochromis niloticus	*exotic*	*detrivores*	*Tolerant*
	Oreochromis variabilis	*exotic*	*Omnivore*	*Tolerant*
	Paralabidochromis "black para"	*native*	*Detrivores*	*Intolerant*
	Paralabidochromis igeneopinis	*native*	*Omnivore*	*Intolerant*
	Paralabidochromis red cribensis	*native*	*Omnivore*	*Intolerant*
	Paralabidochromis rockcrebensis	*native*	*Omnivore*	*Intolerant*
	Paralabidochromis scarlet anal	*native*	*Omnivore*	*Intolerant*
	Paralabidochromis sp	*native*	*Omnivore*	*Intolerant*
	Paralabidochromis thicklip	*native*	*Omnivore*	*Intolerant*
	Paralabidochromis yellow rock picker	*native*	*Omnivore*	*Intolerant*

	Paralibidochromis victoriae	*native*	*Omnivore*	*Intolerant*
	Prognathochromis shovelmouth	*native*	*Omnivore*	*Intolerant*
	Psammochromis riponianus	*native*	*Omnivore*	*Intolerant*
	Psammochromis sp.	*native*	*Carnivore*	*Intolerant*
	Ptyochromis sauvagei	*native*	*Carnivore*	*Intolerant*
	Ptyochromis sp	*native*	*Carnivore*	*Intolerant*
	Pundamilia macrocephala	*native*	*Carnivore*	*Intolerant*
	Pundamilia pundamilia	*native*	*Omnivore*	*Intolerant*
	Pundamilia riponianus	*native*	*Omnivore*	*Intolerant*
	Pundamulia yellowfin	*native*	*Omnivore*	*Intolerant*
	Purple dorsum	*native*	*Omnivore*	*Intolerant*
	R.cribensis	*native*	*Omnivore*	*Intolerant*
	***Harpagochromis "shovel mouth*"**	*native*	*Omnivore*	*Intolerant*
	X. phytophagus	*native*	*Carnivore*	*Intolerant*
	X.pink dorsal	*native*	*Omnivore*	*Intolerant*
	Yssichromis earthquake	*native*	*Omnivore*	*Intolerant*
Mormyridae	*Gnathonemius longibarbis*	*native*	*Omnivore*	*Tolerant*
Claridae	*Clarias gariepinus*	*native*	*Omnivore*	*Tolerant*
Latidae	*Lates niloticus*	*exotic*	*Carnivore*	*Tolerant*
Mormyridae	*Mormyrus kannume*	*native*	*Carnivore*	*Tolerant*
Protopteridae	*Protopterus aethiopicus*	*native*	*Carnivore*	*Tolerant*
Mochokidae	Synodontis afrofisherie	*native*	*Omnivore*	*Tolerant*
Mochokidae	*Synodontis victoriae*	*native*	*Carnivore*	*Tolerant*
Bagridae	*Bagrus docmac*	*native*	*Carnivore*	*Tolerant*
Cyprinidae	***Labeo barbus****altinialis*	*native*	*Omnivore*	*Tolerant*
Cyprinidae	*Rastrineobola argentae*	*native*	*Omnivore*	*Intolerant*
Alestidae	*Brycinus sadleri*	*native*	*Omnivore*	*Intolerant*

Lates niloticus was the most dominant fish species with a percentage composition of 13.82%, *C. zilli* 7.92%, *B. altinialis* 2.67%, *M. kannume* 1.8%,*O. niloticus* 0.54% and *B. docmac* 0.41% then remaining contributed 72% and haplochromines species contributed the highest percentage(Table 4-2).

Table 4-2: Percentage occurrence and abundance of fish within Upper Victoria Nile

Fish species	Occurrence	% Occurrence	Abundance	% Abundance
Astatochromis pink dorsal	8	0.47	37	0.34
Astatoreochromis alluaudi	15	0.89	38	0.35
Astatotilapia "red dorsum"	44	2.60	472	4.29
Astatotilapia blue	2	0.12	4	0.04
Astatotilapia brownie	110	6.50	501	4.56
Astatotilapia elongate	4	0.24	30	0.27
Astatotilapia nubila	15	0.89	33	0.30
Astatotilapia purple dorsum	18	1.06	6	0.05
Astatotilapia red anal	11	0.65	777	7.07
Astatotilapia scarlet anal fin	7	0.41	52	0.47
Astatotilapia spp	39	2.30	850	7.73
Astatotilapia yellow	15	0.89	2	0.02
Bagrus docmac	30	1.77	45	0.41
Barbus altinialis	6	0.35	294	2.67
Brycinus sadleri	11	0.65	19	0.17
Clarias gariepinus	99	5.85	7	0.06
Coptodon zilli	85	5.02	871	7.92
Curved head Neochromis	74	4.37	23	0.21
Gaurochromis	2	0.12	1424	12.95
Gnathonemius longibarbis	9	0.53	157	1.43
Haplochromines	13	0.77	804	7.31
Harpagochromis "shovel mouth"	10	0.59	148	1.35
Harpagochromis guiarti	26	1.54	2	0.02
Labeo victorianus	13	0.77	8	0.07
Lates niloticus	364	21.51	1519	13.82

Lipochromis microdon	1	0.06	3	0.03
Lipochromis pavidens	1	0.06	58	0.53
Lithochromis	7	0.41	33	0.30
Mbipia "blue"	9	0.53	4	0.04
Mbipia mbipi	42	2.48	164	1.49
Mbipia red	1	0.06	1	0.01
Mbipia yellow	9	0.53	26	0.24
Mollusc crusher	3	0.18	488	4.44
Mormyrus kannume	190	11.23	204	1.86
Neochromis	16	0.95	16	0.15
Neochromis elongate	0	-	1	0.01
Neochromis greenwoodi	0	-	168	1.53
Neochromis nigricans	6	0.35	29	0.26
Neochromis rufocaudalis	0	-	364	3.31
Neochromis thichlips	0	-	29	0.26
Oreochromis leucostictus	3	0.18	3	0.03
Oreochromis niloticus	59	3.49	59	0.54
Oreochromis variabilis	33	1.95	39	0.35
Paralabidochromis "black para"	0	-	0	-
Paralabidochromis igeneopinis	0	-	0	-
Paralabidochromis red cribensis	1	0.06	2	0.02
Paralabidochromis rockcrebensis	6	0.35	3	0.03
Paralabidochromis scarlet anal	0	-	0	-
Paralabidochromis sp	0	-	0	-
Paralabidochromis thicklip	2	0.12	1	0.01
Paralabidochromis yellow rock picker	0	-	0	-
Paralibidochromis victoriae	10	0.59	24	0.22

Prognathochromis shovelmouth	0	-	0	-
Protopterus aethiopicus	0	-	0	-
Psammochromis aelocephalus	0	-	0	-
Psammochromis riponianus	57	3.37	514	4.68
Psammochromis sp.	18	1.06	25	0.23
Ptyochromis sauvagei	6	0.35	9	0.08
Ptyochromis sp	1	0.06	2	0.02
Pundamilia macrocephala	0	-	0	-
Pundamilia pundamilia	30	1.77	168	1.53
Pundamilia riponianus	3	0.18	0	-
Pundamulia (black)	0	-	0	-
Pundamulia (orange anal)	0	-	0	-
Pundamulia orange tail	0	-	0	-
Pundamulia yellowfin	0	-	0	-
Purple dorsum	0	-	0	-
Shovel mouth	0	-	0	-
Synodontis afrofischeriae	117	6.91	401	3.65
Synodontis victoriae	31	1.83	31	0.28
X. phytophagus	0	-	0	-
X.pink dorsal	0	-	0	-
Yssichromis earthquake	0	-	0	-

Though for the combined fish samples of 2008 to 2019 recorded ,*Lates niloticus* 62.79%, *Oreochromis niloticus* 23.51%, *Mormyrus kannume* 13.64%; other species were ≤0.06% each. Several fish species, namely X pink dorsal and *Yssichromis earthquake* occurred at (ST3), *Neochromis thiclips* at (ST1) and (ST3), Astatochromis pink dorsal at (ST4),Purple dorsum at (ST2)*Pundamilia pundamilia*, *Pundamilia riponians* at (ST1) and *Pundamilia yellow* fin at (ST7) then the rest occurred in almost all stations.Station (ST6) had the highest mean fish catch of 707.40±39.05while (ST6) had the least 212.32±6.39along the river (Figures4-38).ANOVA test showed $F=4.473$; $df = 107$; $p<0.05$ spatially and the $F=54.878$; $df =43$; $p<0.05$ on the temporal basis.

On temporal scale, the highest mean fish abundance (1,147.12±9.76) was recorded in 2019 while the least (203.137±0.31) was estimated in 2018 (Figure 4-39). The result revealed a fluctuating trend between the sampled periods. There was a significant variation between the sampled periods ($F=54.878$; $df = 43$; $p < 0.05$) from 2014 to 2019 in the study area. The distribution of fish species along the sampling stations are shown in (Table 4-2). The results were compared with outputs from 2008 to 2013 that showed that the mean abundance ranged from 235.76± 6.98 in 2009 to 632.71±5.63 in 2010 (Figure 4-40).

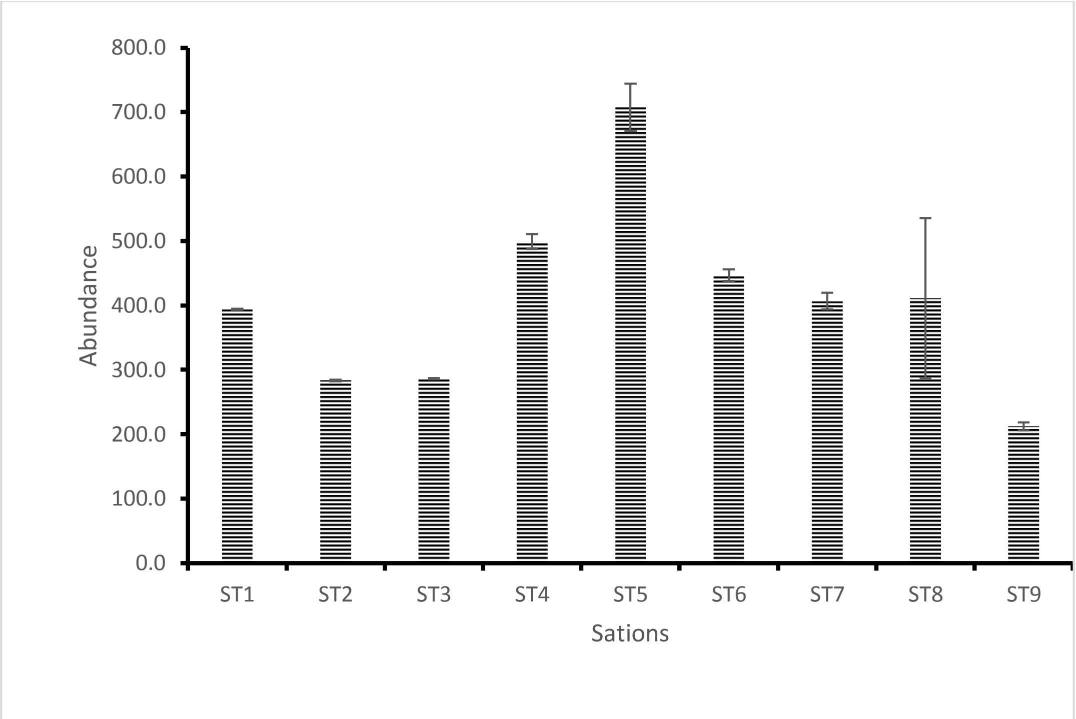

Figure 4-38: Mean Fish a bundance(± SE) for different sampled stations

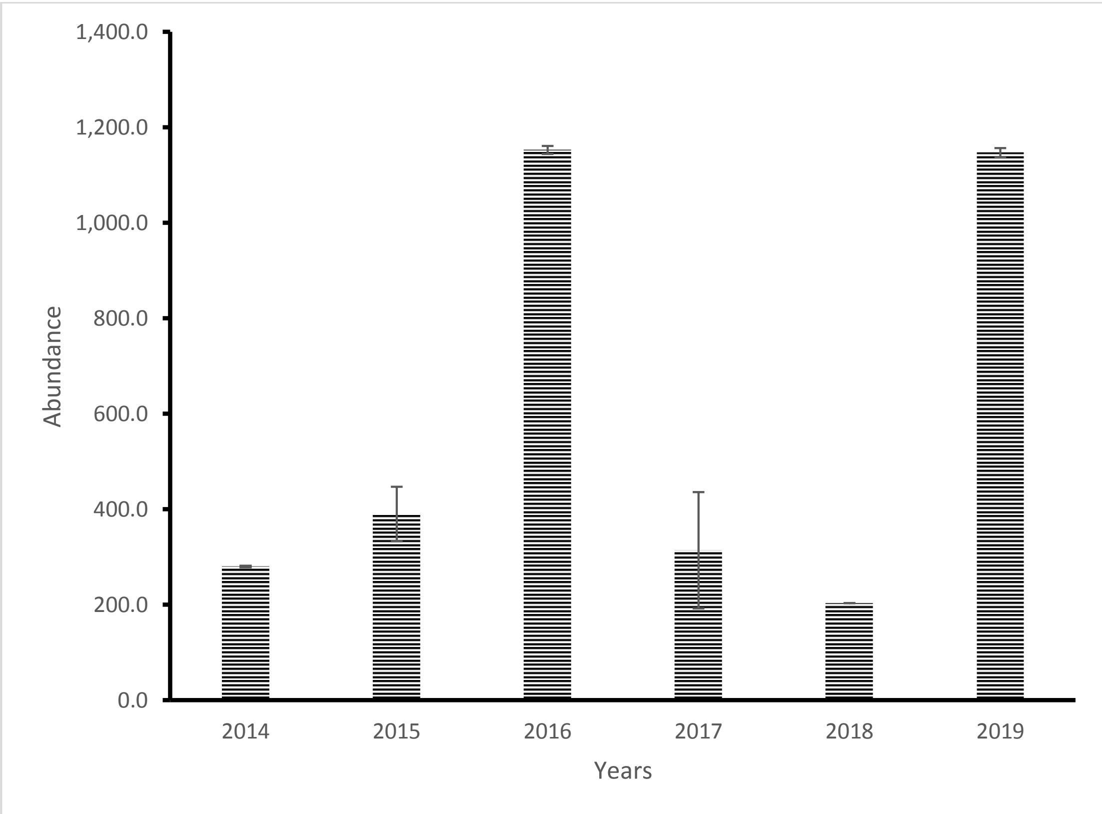

Figure 4-39: Mean Fish abundance(± SE) for different sampled periods (2014-19)

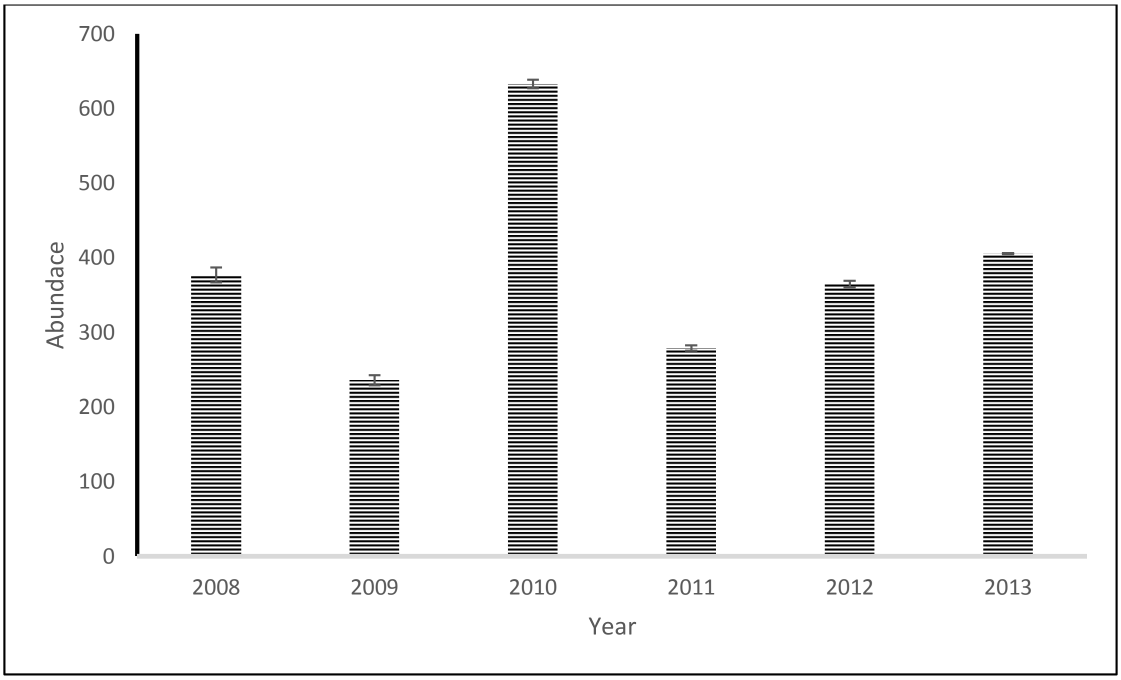

Figure 4-40: Mean Fish abundance(± SE) for different sampled periods (2008-13)

4.3.3 Mean Fish Diversity Indices

4.3.3.1 Spatial trend for Mean diversity indices

The lowest (0.58 ± 0.06) and highest (1.25 ± 0.04) means for Shannon-Wiener index were computed at (ST5) and(ST9), respectively (Figure 4-41). The index exhibited a significant variation F= 10.353; df; 107; p<0.05.

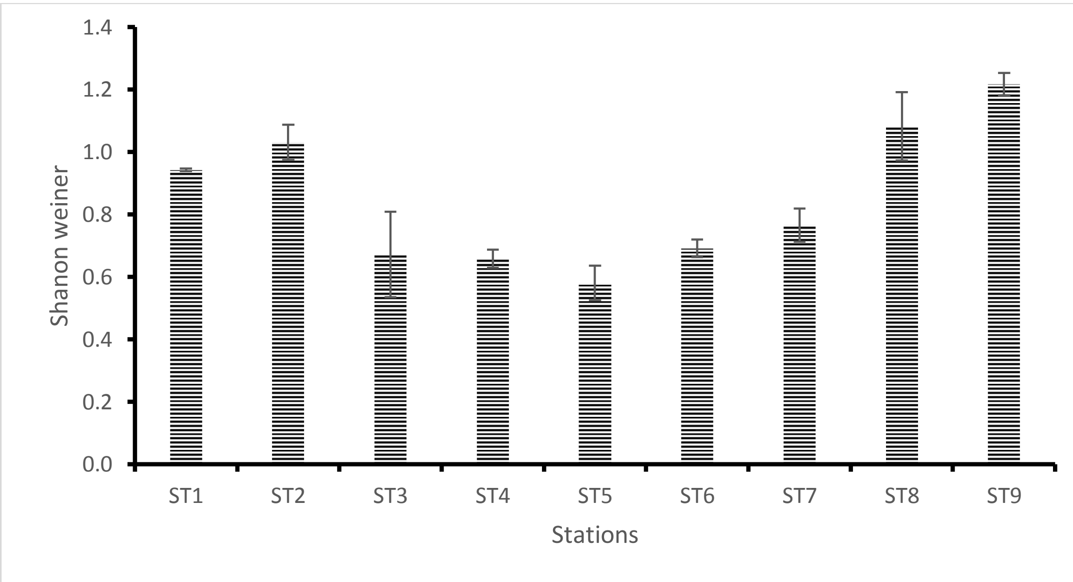

Figure 4-41: Mean Shannon-Wiener diversity index at different sampling stations (2014-2019)

A similar trend was exhibited in Simpson index of diversity.(ST4) had the lowest (0.80±0.01) while ST8had the highest (0.94±0.00) (Figure 4-42).There was a significant difference F=14.256; df =107 $p<0.05$ observed downstream the upper Victoria Nile.

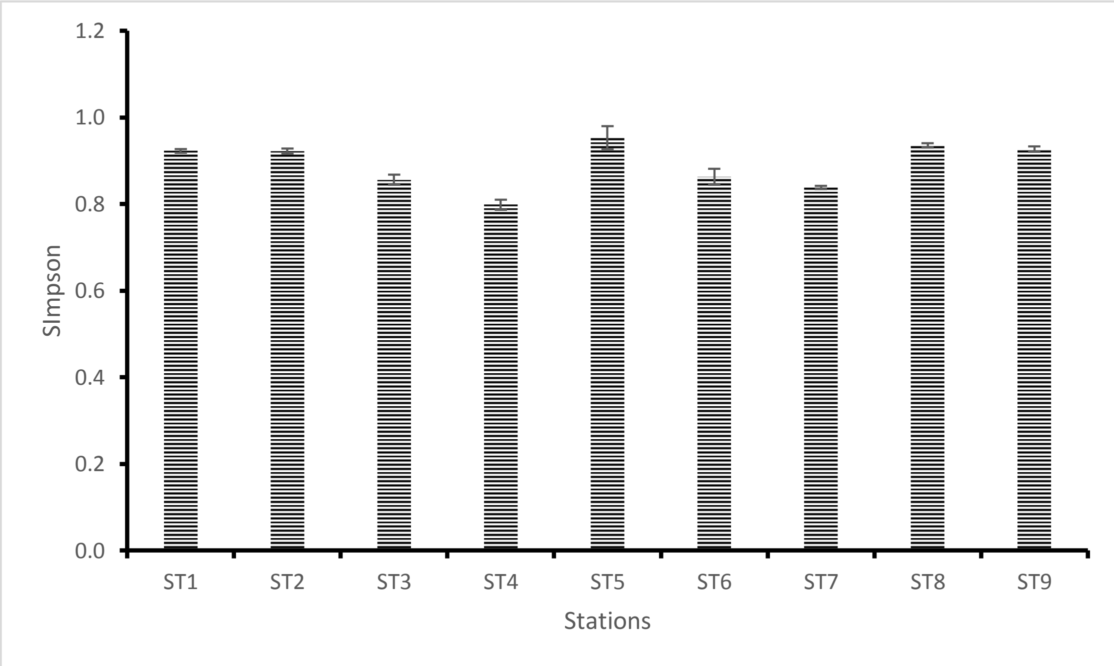

Figure 4-42: Mean Simpson index at different sampling stations (2014-2019)

The lowest mean evenness index (0.11±0.00) was recorded at **(ST5)** while the highest (0.20±0.01) was recorded at (ST8) (Figure 4-43).

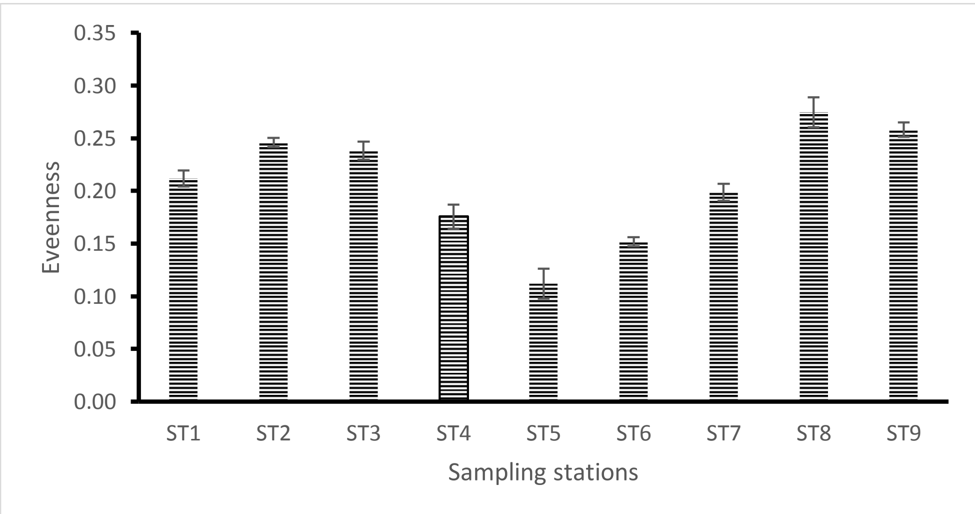

Figure 4-43: Mean evenness index at different sampling stations (2014-2019)

There was a significant difference between stations with F=15.818; df = 107; $p<0.05$ on the upper Victoria Nile.

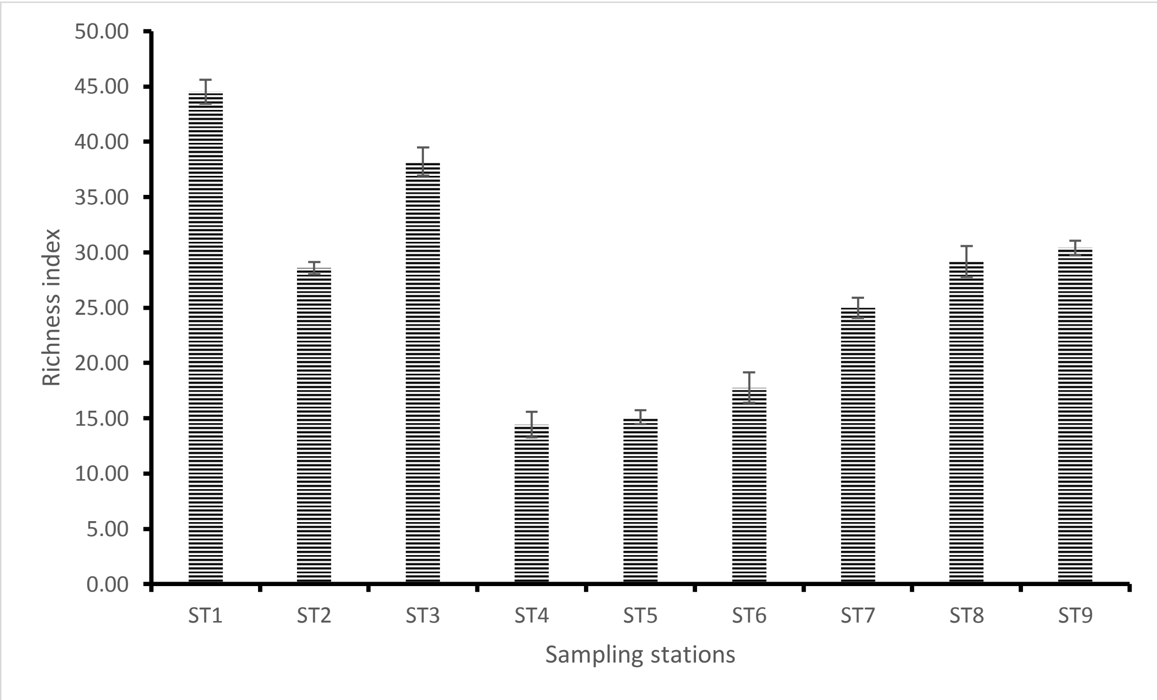

Figure 4-44: Mean species richness at different sampling stations (2014-2019)

Species richness ranged from 14.43±1.17 (ST4) to 44.53± 1.08 (ST1) (Figure 4-44). Means exhibited significant variation F=73.002; df= 107; $p<0.05$ between the sampled stations.

Table 4-3: Distribution of fish species along the sampling stations

Species	(ST1)	(ST7)	(ST2)	(ST6)	(ST5)	(ST4)	(ST8)	(ST3)	(ST9)
Astatochromis pink dorsal	-	x	-	-	-	-	-	x	-
Astatoreochromis alluaudi	xx	x	x	-	-	-	xx	xx	x
Astatotilapia "red dorsum"	x	-	x	-	-	-	x	x	x
Astatotilapia brownie	xxx	xxx	xxx	x	xx	x	x	xxx	xxx
Astatotilapia elongate	x	x	-	x	-	-	-	x	x
Astatotilapia nubile	-	-	-	x	-	-	-	x	x
Astatotilapia purple dorsum	x	x	-	-	-	-	-	x	x
Astatotilapia red anal	x	-	x	-	-	-	-	x	-
Astatotilapia scarlet anal fin	x	x	-	-	-	-	x	-	x
Astatotilapia spp	xx	x	xx	x	-	x	x	x	x
Astatotilapia yellow	x	-	-	-	-	-	-	-	-
Bagrus docmac	x	x	x	x	xx	xx	x	x	-
Barbus altinialis	x	x	x	x	x	x	-	x	x
Brycinus sadleri	x	-	-	-	-	-	-	x	-
Clarias gariepinus	x	x	x	x	-	x	x	x	x
Coptodon zilli	xx	xx	xx	x	x	x	x	xx	xx
Curved head Neochromis	-	-	-	-	-	-	-	x	-
Gaurochromis	x	-	-	-	-	-	-	-	-
Gnathonemius longibarbis	-	-	-	x	x	x	-	-	-
Haplochromines	-	x	x	-	-	-	x	-	x
Harpagochromis "shovel mouth"	-	-	-	-	-	-	-	-	x
Harpagochromis guiarti	xx	x	x	-	-	-	x	x	x

Lates niloticus	xxx	xxx	xxx	xx	xxx	xxx	xx	xxx	xxx
Lipochromis microdon	-	-	x	-	-	-	-	-	-
Lipochromis pavidens	x	-	-	-	-	-	-	-	x
Lithochromis	x	-	-	x	-	-	x	x	x
Mbipia "blue"	xx	xx	xx	x	x	x	x	x	xx
Mbipia mbipi	x	-	-	-	-	-	-	-	-
Mbipia red	-	-	-	x	-	-	-	-	-
Mbipia yellow	xxx	xxx	xx	xx	xxx	xxx	x	xxx	xx
Mormyrus kannume	-	-	-	x	x	x	-	-	-
Neochromis elongate	x	-	x	-	-	-	-	x	-
Neochromis greenwoodi	-	x	-	-	-	-	x	-	-
Neochromis nigricans	x	-	x	-	x	-	-	x	-
Neochromis rufocaudalis	-	-	-	-	-	-	-	-	x
Neochromis thichlips	x	-	-	-	-	-	-	x	-
Oreochromis leucostictus	xx	xx	x	x	-	-	x	xx	xx
Oreochromis niloticus	xx	x	xx	x	x	x	x	xx	x
Oreochromis variabilis	-	-	x	-	-	-	-	-	-
Paralabidochromis "black para"	x	x	-	-	x	-	-	-	-
Paralabidochromis igeneopinis	-	-	-	-	-	-	-	-	x
Paralabidochromis red cribensis	x	-	-	-	-	-	-	-	-
Paralabidochromis rockcrebensis	x	-	-	-	-	-	-	-	-
Paralabidochromis scarlet anal	-	x	-	-	-	-	-	-	x
Paralabidochromis sp	x	-	-	-	-	-	-	-	-
Paralabidochromis thicklip	x	-	-	-	-	-	-	x	-

Paralabidochromis yellow rock picker	x	-	x	-	-	-	-	-	-
Paralibidochromis victoriae	x	-	x	-	-	-	-	x	-
Prognathochromis shovelmouth	x	-	-	-	-	-	x	-	-
Protopterus aethiopicus	xx	xx	-	x	x	-	x	x	x
Psammochromis riponianus	x	x	x	x	-	-	x	x	x
Psammochromis sp.	x	-	-	-	-	-	x	-	-
Ptyochromis sauvagei	x	x	x	-	-	-	-	x	x
Ptyochromis sp	x	-	-	-	-	-	-	-	-
Pundamilia macrocephala	xx	x	-	x	-	-	x	x	-
Pundamilia pundamilia	x	-	-	-	-	-	-	x	-
Pundamilia riponianus	x	-	-	-	-	-	-	-	-
Pundamulia yellowfin	-	x	-	-	-	-	-	-	-
Purple dorsum	-	-	x	-	-	-	-	-	-
R.cribensis	-	-	-	-	-	-	-	-	x
Harpagochromis "shovel mouth"	x	x	-	x	x	-	x	x	x
Synodontis afrofischeri	xxx	xx	xxx	x	x	x	x	xxx	xx
Synodontis victoriae	x	x	-	-	x	-	-	x	x
X. phytophagus	x	x	x	-	-	-	-	-	x
X.pink dorsal	-	-	-	-	-	-	-	x	-
Yssichromis earthquake	-	-	-	-	-	-	-	x	-

xxx : species dominated the station
xx : species were moderately present
x : species found in few numbers
- : absent

4.4Temporal trend for Mean diversity Indices

The lowest mean Shannon-Wiener index of0.66± 0.01 was recorded in 2016 whereas the highest 0.76 ± 0.08 was recorded in 2014. Simpson index ranged from 0.74 ± 0.01 in 2015to 0.84± 0.01 in 2011. Mean evenness index was lowest 0.14 ± 0.00 in 2017 and highest 0.25 ± 0.00 in 2019. Mean species richness index varied from 6.75± 0.64 in 2017 to 23.75± 0.88 in 2014. The above indices revealed a general slight increasing trend. Evenness and Richness Shannon and Simpson did exhibit statistically significant variation of $p<0.05$ for the whole period of sampling (Figures 4-41, 4-42, 4-43, 4-44).

4.4.1Fish –Based Index of Biotic Integrity (FIBI)

The mean FIBI ranged from 25.86±0.01at(ST4) to 32.89±0.01 at (ST6) (Figure 4-45).

There was a statistically significant variation $F=8.502$; $df = 107$; $p<0.05$ between the stations.

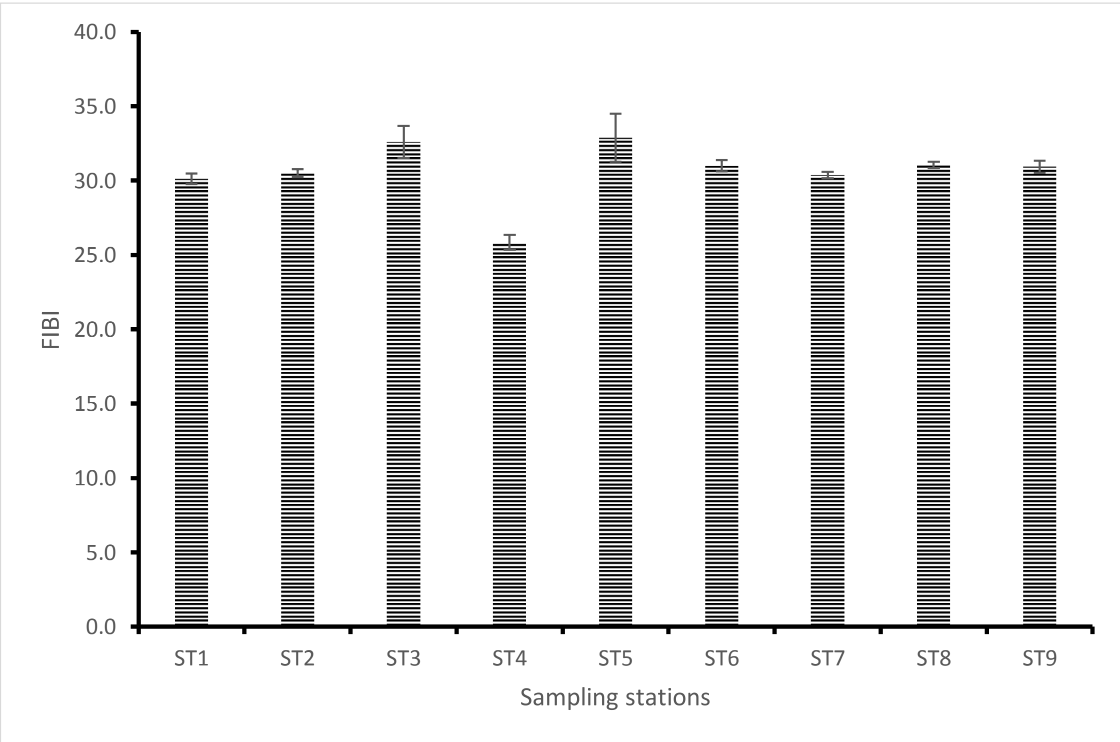

Figure 4-45: Mean FIBI at different sampling stations

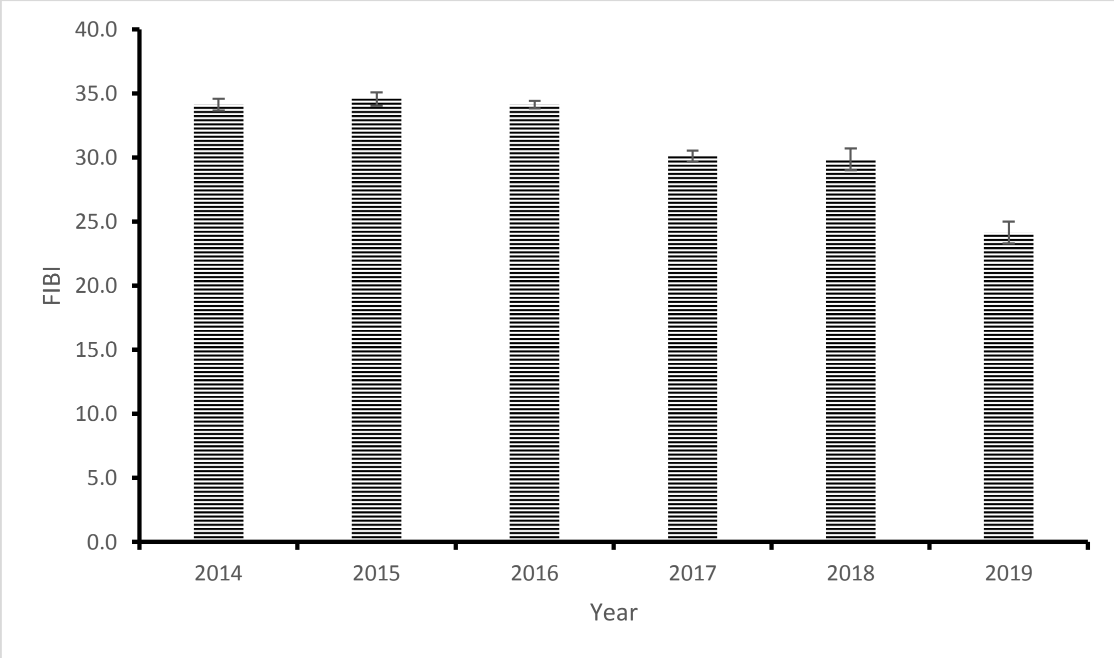

Figure 4-46: Mean FIBI at different sampling period

The lowest FIBI mean of (24.15±0.84) was recorded in 2019 while the highest (34.57±0.53) was recorded in 2015(Figure 4-46).ANOVA test recorded a significance of F=44.929; df= 107; p<0.05. In the previous years of 2008 to 2013, the fishery's mean abundance ranged between 29.83±1.11 to 36.83±1.47 in the respective years (Figure 4-47).

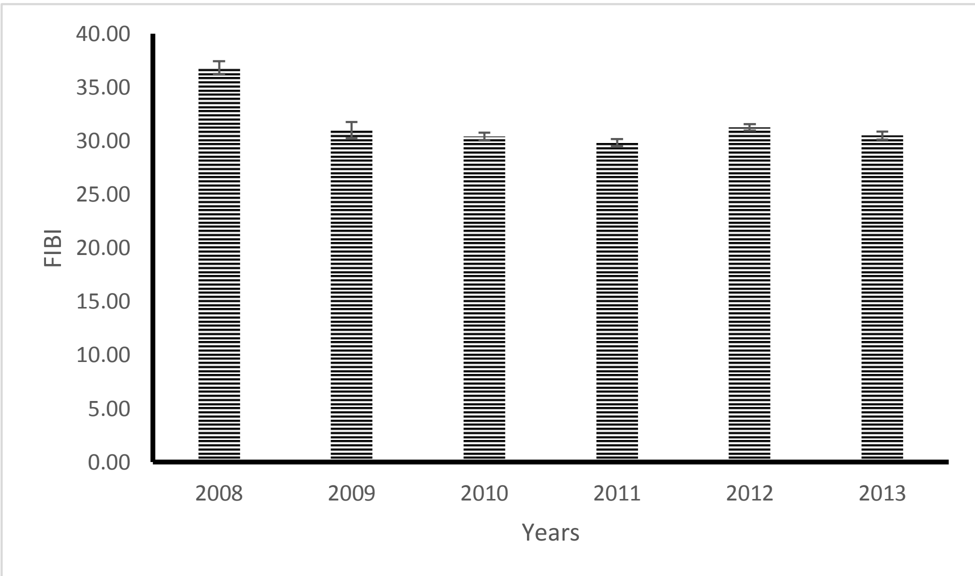

Figure 4-47: Mean FIBI at different sampling period (2008-13)

4.4.2 Correlation Analyses for the Mean Value of Diversity Indices of Upper Victoria Nile

Pearson correlation analysis between the indices and water quality parameters showed that FIBI had a strong positive correlation ($p < 0.05$, $R^2 > 0.5$) with species richness and abundance (Tables 4-4 A&B, 4-5). FIBI also had a medium negative correlation with Shannon-Wiener index and HQI and Evenness.

Table 4-4; Mean values (± SE) for diversity indices in different sampling years (A and B)

A

	2014	**2015**	**2016**	**2017**	**2018**	**2019**
Richness	23.75(0.65)	20.71(0.78)	23.50(1.16)	6.75(0.65)	21.85(0.51)	**21(0.75)**
Simpson	0.95(0.00)	0.73(0.16)	0.84(0.01)	0.93(0.00)	0.85(0.02)	**0.84(0.02)**
Shannon	0.75(0.08)	0.77(0.02)	0.65(0.01)	0.69(0.01)	0.71(0.01)	**0.99(0.13)**
Evenness	0.21(0.00)	0.16(0.01)	0.15(0.00)	0.14(0.00)	0.22(0.00)	**0.23(0.00)**

B

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
RICHNESS	28.00(1.03)	27.33(1.20)	17.16(0.58)	25.00(0.37)	34.12(0.69)	19.12(0.61)
Simpson	0.80(0.04)	0.83(0.02)	0.92(0.00)	0.96(0.01)	0.83(0.01)	0.91(0.02)
Shannon	1.23(1.08)	1.09(0.05)	1.00(0.09)	1.69(1.98)	0.75(0.06)	0.71(0.05)
Evenness	0.21(0.01)	0.25(0.01)	0.22(0.00)	0.16(0.01)	0.21(0.01)	0.16(0.00)

HQI had a strong positive correlation with species richness and fish abundance metric. On the other hand, HQI correlated with evenness, total phosphorous concentration, and temperature. FIBI strongly correlated with other parameters like Temperature, NO2-N (µg/L), and TN (µg/L). Shannon-Wiener diversity index had a positive correlation with evenness, Simpson index, species richness, temperature, Conductivity and SDS. Simpson index correlated positively with temperature, conductivity, evenness, and TDS. Fish abundance correlated positively with DO concentration, SD, Temperature, pH, evenness and TSS. Mean values for diversity indices in different sampling years over time and space recorded statistical variations. Then on the Richness, Simpson, Shannon, and Evenness showed a fluctuation trend in the years if samplings (Table 4-4).

4.4.3Flow rate variations

The flow rate for the whole period of samplings such as 2004-2019 ranged between 0.04 - 0.17m/s. The lowest was recorded in ST2 of 0.04m/s and highest in ST9 with 0.17m/s.

Table 4-5: Pearson correlation matrix on the Ecosystem parameters Upper Victoria Nilefor the current study

	SD (m)	DO (mg/L)	T °C	pH	Cond. (µScm-1)	NH4-N (ug/L)	NO2-N (µg/L)	NO3-N (µg/L)	PO4-P (µg/L)	TP (µg/L)	TN (µg/L)	TSS (mg/L)	Sum HQI	RICHNESS	Simpson	Shannon	Evenness	FIBI	Abundance
SD (m)	1																		
DO (mg/L)	-.159	1																	
T °C	.134	-.495**	1																
pH	.281	-.545**	.189	1															
Cond. (µScm-1)	-.274	.078	.029	-.190	1														
NH4-N (ug/L)	-.030	.239	-.312*	-.018	-.098	1													
NO2-N (µg/L)	-.248	-.201	.110	-.049	.381*	.483**	1												
NO3-N (µg/L)	-.076	.079	-.056	-.251	.102	.116	.279	1											
PO4-P (µg/L)	.203	.357*	-.472**	-.011	-.450**	.286	-.485**	-.136	1										
TP (µg/L)	.164	-.481**	.172	.229	-.082	-.255	-.119	-.249	.163	1									
TN (µg/L)	-.072	.063	.223	-.075	.053	-.449**	-.221	-.466**	-.274	-.372*	1								
TSS (mg/L)	-.026	-.059	.303*	.039	.157	-.233	.028	.191	-.696**	-.250	.154	1							
Sum HQI	.064	.165	-.378*	-.001	-.289	.517**	.119	.191	.316*	-.258	-.201	-.231	1						
RICHNESS	-.105	.435**	-.366*	-.476**	.492**	.085	.009	.160	-.003	-.249	.038	.017	.177	1					
Simpson	-.087	.075	.057	-.074	-.087	-.041	-.016	-.051	-.101	-.072	.103	.132	.127	-.011	1				
Shannon	.002	.068	.185	-.069	.035	-.192	-.079	.125	-.327*	-.124	.082	.355*	-.215	.125	-.008	1			
Evenness	.301*	.179	-.402**	-.008	-.093	.532**	-.009	.094	.482**	.060	-.430**	-.321*	.461**	.378*	-.261	-.023	1		
FIBI	-.100	.174	.299*	-.333*	.161	-.738**	-.354*	.079	-.229	-.064	.513**	.249	-.404**	.244	.145	.179	-.358*	1	
Abundance	-.518**	.542**	-.462**	-.358*	.257	.520**	.350*	.052	.151	-.200	-.241	-.206	.257	.285	-.044	-.295	.210	-.208	1

4.6 Determination of Population Dynamics Of The Fishes In The Upper Victoria Nile

This objective outlined the population characteristics of the main fishes of the UVN as mentioned below.

4.6.0 Population characteristics of Nile Perch (*Lates niloticus*),

4.6.1 Length –Weight Relationship of Nile Perch (*Lates niloticus*)

Eight hundred and forty-four (844) spacemen of *Lates niloticus* from experimental gillnet were used to develop their length-weight relationship. The total length of the fish caught ranged from 7.4 to 55.2 cm (TL), while the total weight ranged from 3.0 to 3,000 grams. The average length and weight were 17.79 (±0.28) cm TL while the mean weight was 137.29 (±11.29) g (TW). The length-weight relationship recorded,W= $0.008778L^{3.10052}$ (R^2=0.9525) n=844.The length-weight relationship depicted that growth in Nile perch was isometric, meaning its growth in weight and length was proportionate. The relationship is indicated in the figure below (Figure 4.5-1).

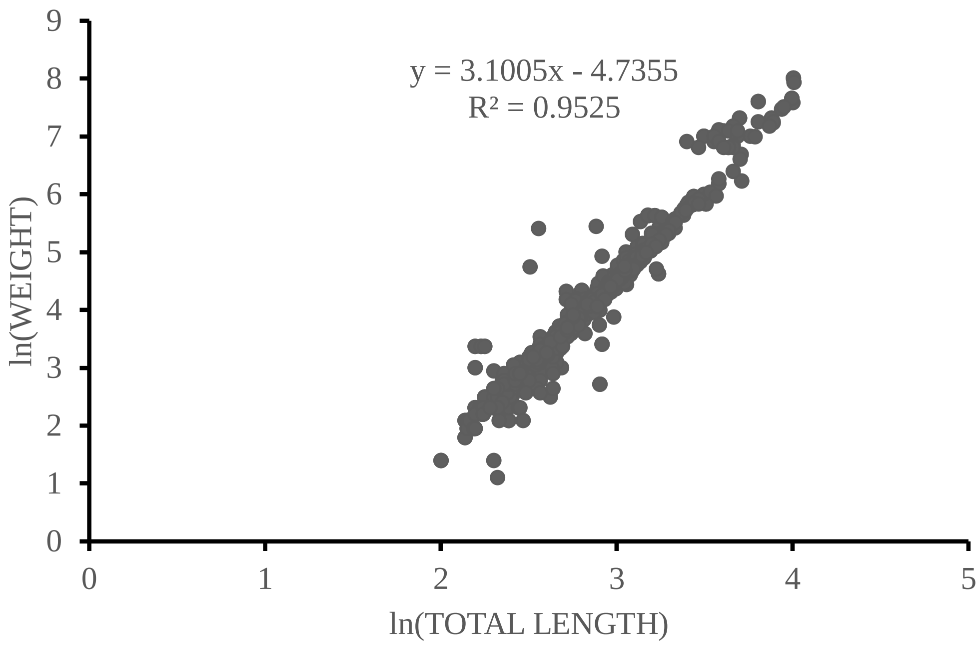

Figure 4.5-1: The length- weight relationship of *Lates niloticus*in the upper Victoria Nile.

ANOVA test indicated a statistically significant difference ($F= 16882.054$, $df= 843$, $P<0.05$) in the length- weight relationship**.** Finding from the study undertaken in 2008-2013 and showed the following: - $a=0.11269$, $b=3.0072$, $R^2=0.9552$, $n=874$. Besides, ANOVA tests showed a statistically significant difference ($F=18606.165$, $df =873$, $P<0.05$).Further, the fishes ranged from 7.4 to 64.1 cm TL and 4.0- 3,000 gram weight.

4.6.2 Growth Parameters of Nile Perch

The output of the FISAT II method for estimating growth parameters for *Lates niloticus*is presented in (Figure 4.5-2).The von Bertalanffy growth parameters of *L. niloticus* were estimated as L_∞ of 90.30 (TL cm) and growth coefficient K=0.36 per year (Figures 4.5-2 &4.5-3). The value of the time was the hypothetical age t_o=-0.27105 when the length of the virtual age was considered zero. R_n (goodness of fist) was estimated to be 0.2131using the ELEFAN-1 method. The longevity t, max was estimated as at t_{max}= 8.1 years as the maximum age for the *Lates niloticus* species recorded. The growth performance indices based on asymptotic length (L_∞) and asymptotic weight (W_∞) were Ø=3.468 per year and Ø=1.994 per year for *L. niloticus* from the riverine of the UVN waters.

These findings were compared with findings from 2008 to 2013 which were and obtained the following; asL_∞ =78.75 (TL cm) and growth coefficient K=0.55 per year, t_o=-0.20267.The longevity t, max was estimated as at t_{max}= 5.3 years.

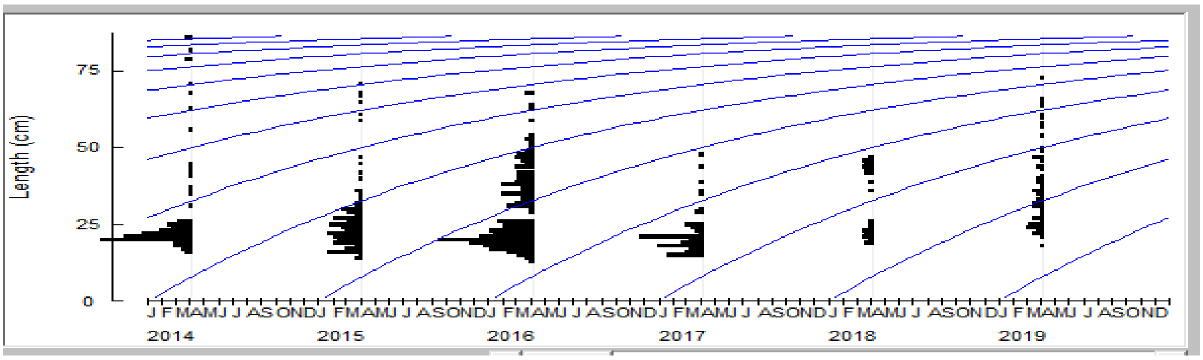

Figure 4.5-2: Total length, von Bertalanffy growth curve for *Lates niloticus* (2014-2019)

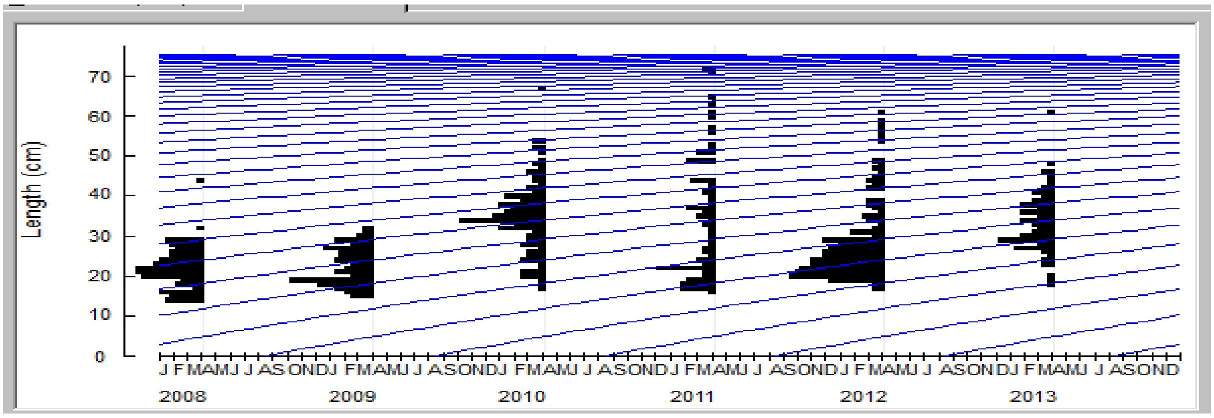

Figure 4.5-3: Total length, von Bertalanffy growth curve for *Lates niloticus* (2008-2013)

4.6.3 Mortality Estimates of *Lates niloticus*

The total mortality rate (Z) of *Lates niloticus* estimated using the catch curve analysis is represented in Figures 4.5-4 &4.5-5. The total mortality estimated Z=1.71 per year was estimated at a 95% confidence interval (CL=1.46-1.95). The value of natural mortality (M) estimated from (Pauly's formulae) was M=0.65 per year using the riverine surface temperature of (RST) 26^{o}C. Thus, the fishing mortality was calculated as F=Z-M=1.06 per year and exploitation ratio (E) was calculated from F/Z=0.62. The ration of length first capture to asymptotic length was Lc/L_{∞} was 0.050. The yield per recruit indicated that the fishery was harvested at 0.02 grams per year on the Upper Victoria Nile (Figure 4.5-4 & 4.5-5). Beverton and Holt's relative yield-per-recruit model indicted indices for sustainable yield as 0.244 for optimum sustainable yield ($E_{0.5}$), 0.474 for maximum sustainable yield (E_{max}) and 0.306 for economic yield ($E_{0.1}$).

Meanwhile the size at first maturity L_{50} for males and females showed that Nile perch was maturing at 30.1 cm TL and 40.3 cm TL for females and males respectively for the years 2014-19 as compared to 23 cm TL length for males only 2008-13 (Figures 4.5-6, 4.5-7,4.5-8, 4.5-9). A comparison was done with data obtained in 2008-13 that showed the population parameters as Z=2.49, M=0.89, F=1.60, E=0.64 yield/recruit=, (E0.1) =0.306, (E0.5) =0.381, (E_{max}) = 0.249 and Y/R=0.03 grams, t_{max}=6 years and t_o=-0.7517 (Figures 4.5-7, 4.5-11, 4.5-13)

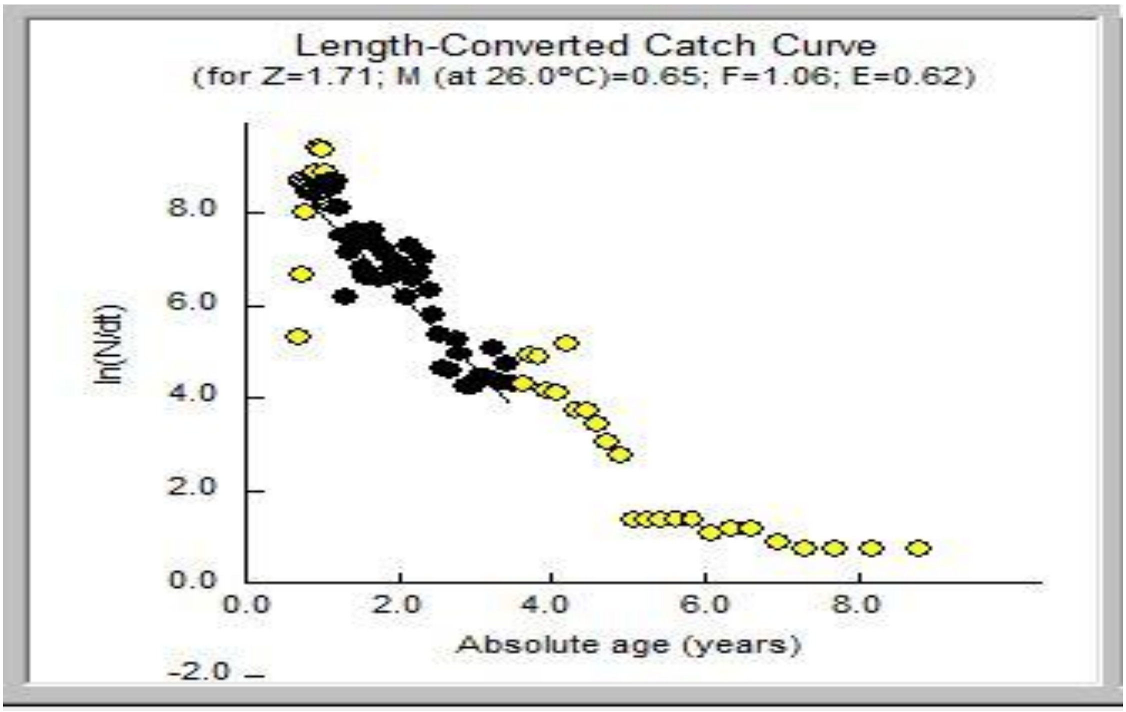

Figure 4.5-4: The growth parameters for *Lates niloticus* sampled (2014-19)

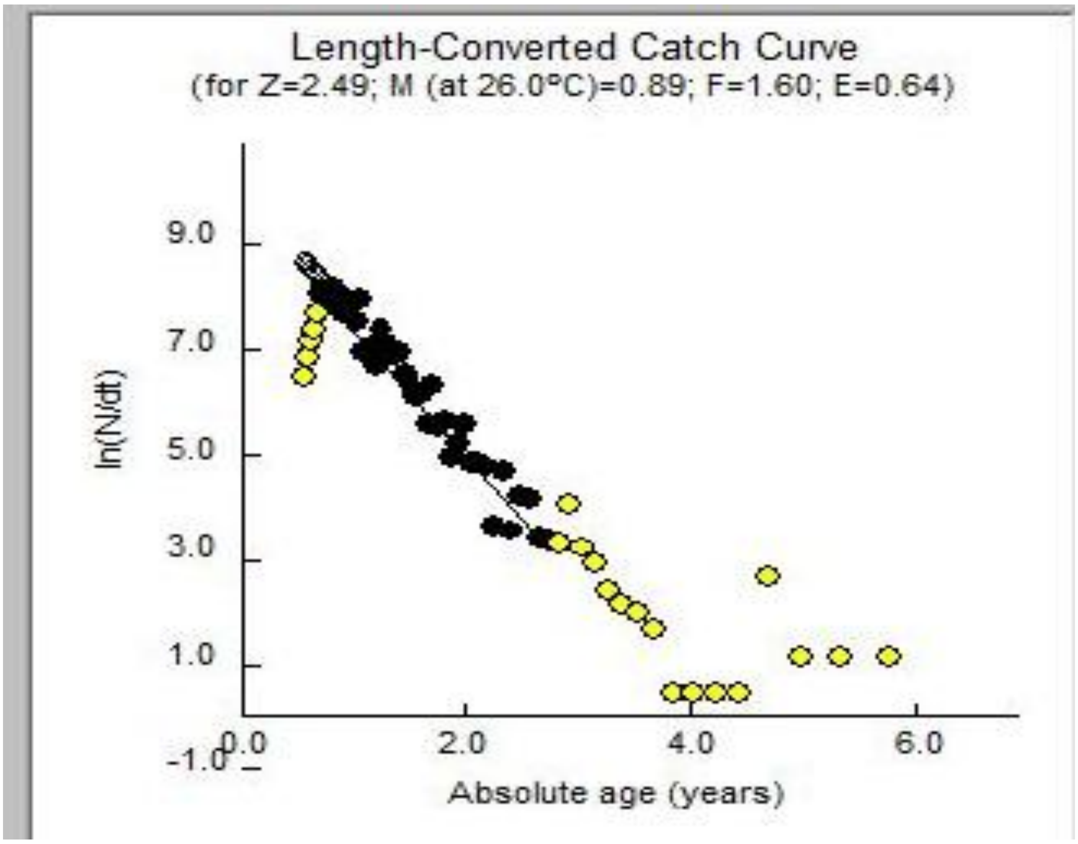

Figure 4.5-5: The growth parameters for *Lates niloticus* sampled (2008-13)

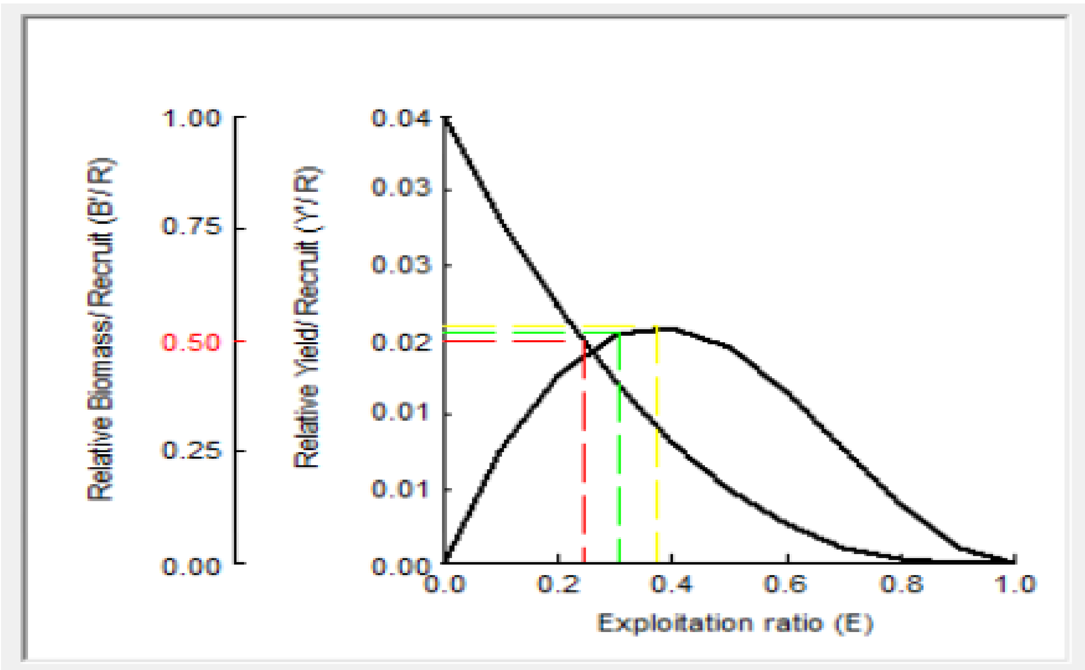

Figure 4.5-6: Indicates the yield per recruit analysis (knife–edge selection Isopleth) the Exploitation rate of the *Lates niloticus* from the experimental data sampled in the Upper Victoria Nile (2014-2019).

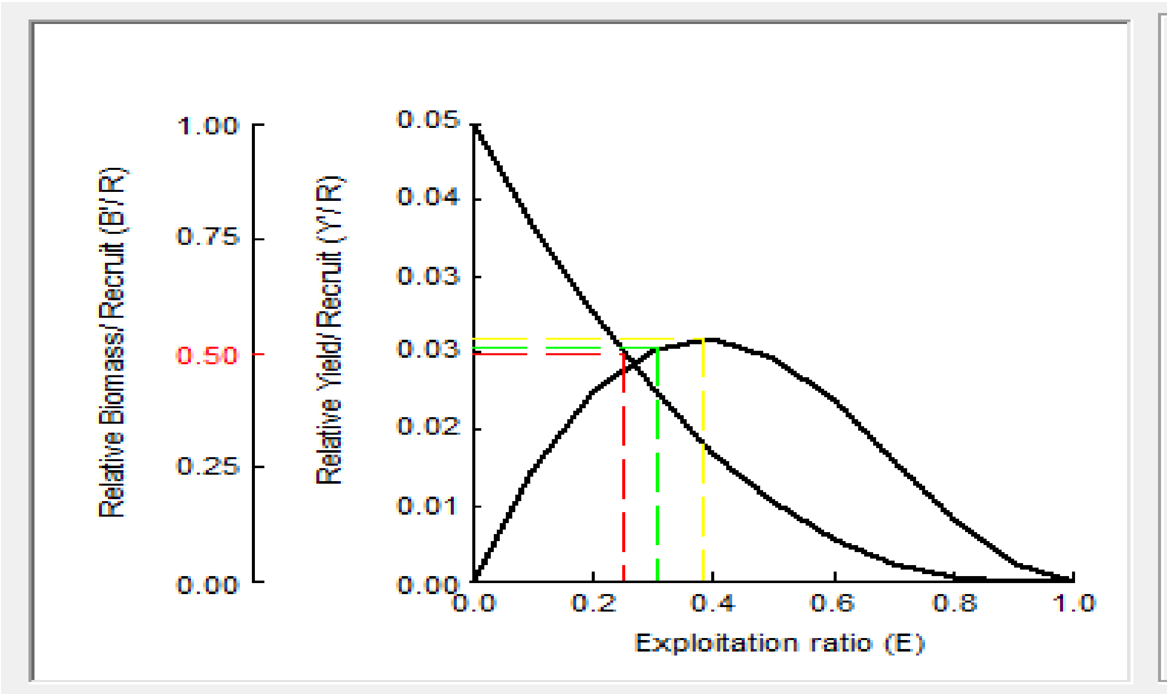

Figure 4.5-7: Indicates the yield per recruit analysis (knife–edge selection Isopleth) the Exploitation rate of the *Lates niloticus* from the experimental data sampled in the Upper Victoria Nile (2008-2013).

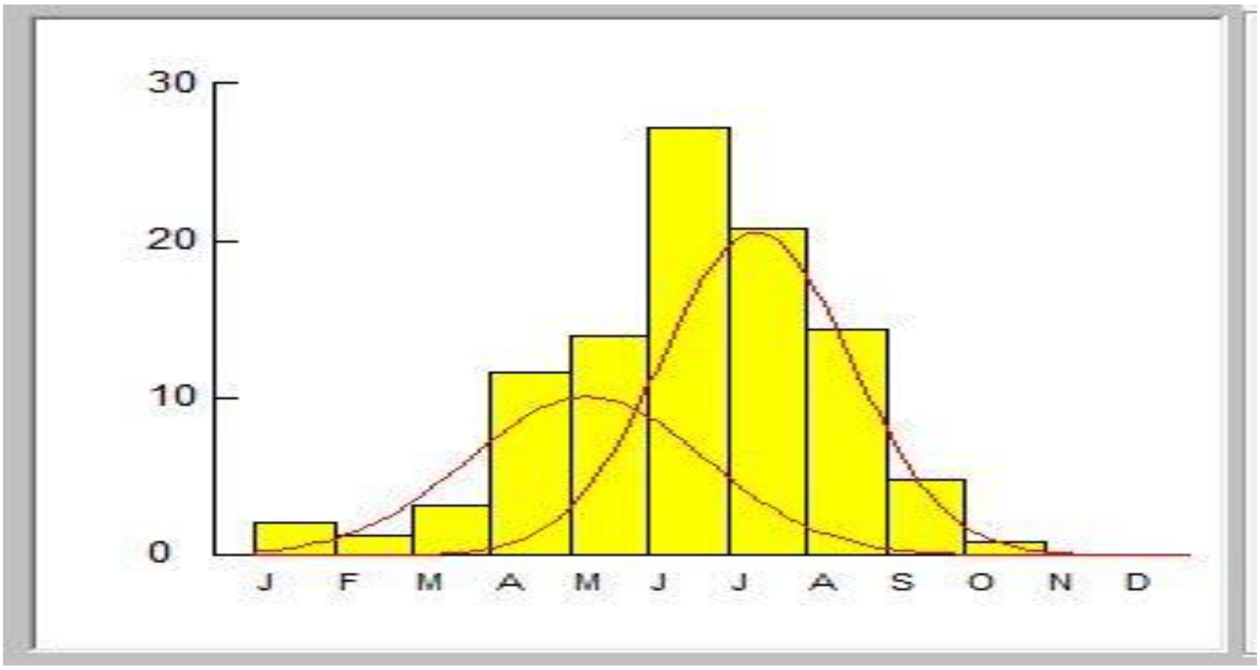

Figure 4.5-8: Recruitment patterns for *L. niloticus* UVN waters (2014-2019)

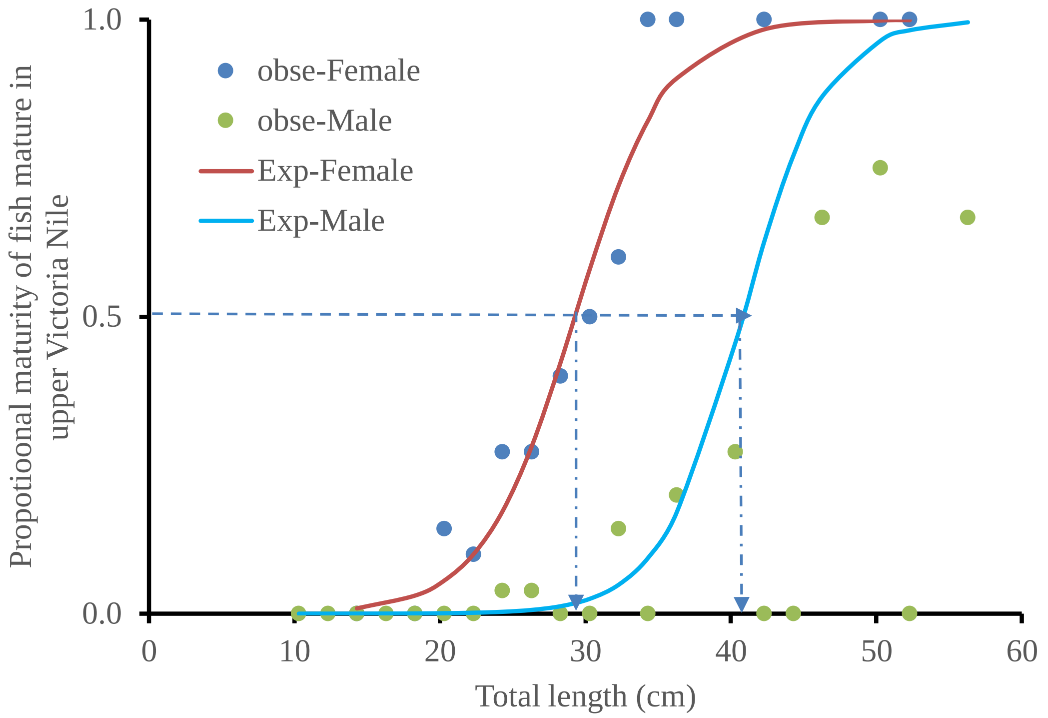

Figure 4.5-9: Maturity proportions for male (A) at 30.1 cm TL and Females at 40.3 cm TL for *Lates niloticus* UVN waters (2014-2019).

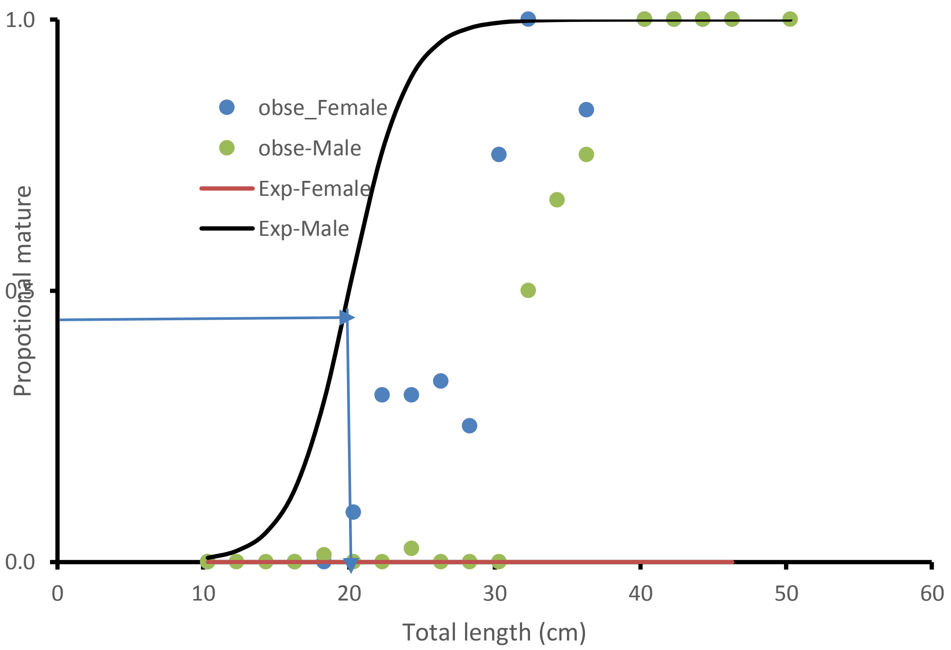

Figure 4.5-10: Maturity proportions for male (A) at 23 cm TL and Females at flat shape cm TL for *Lates niloticus* UVN waters (2008-2013).

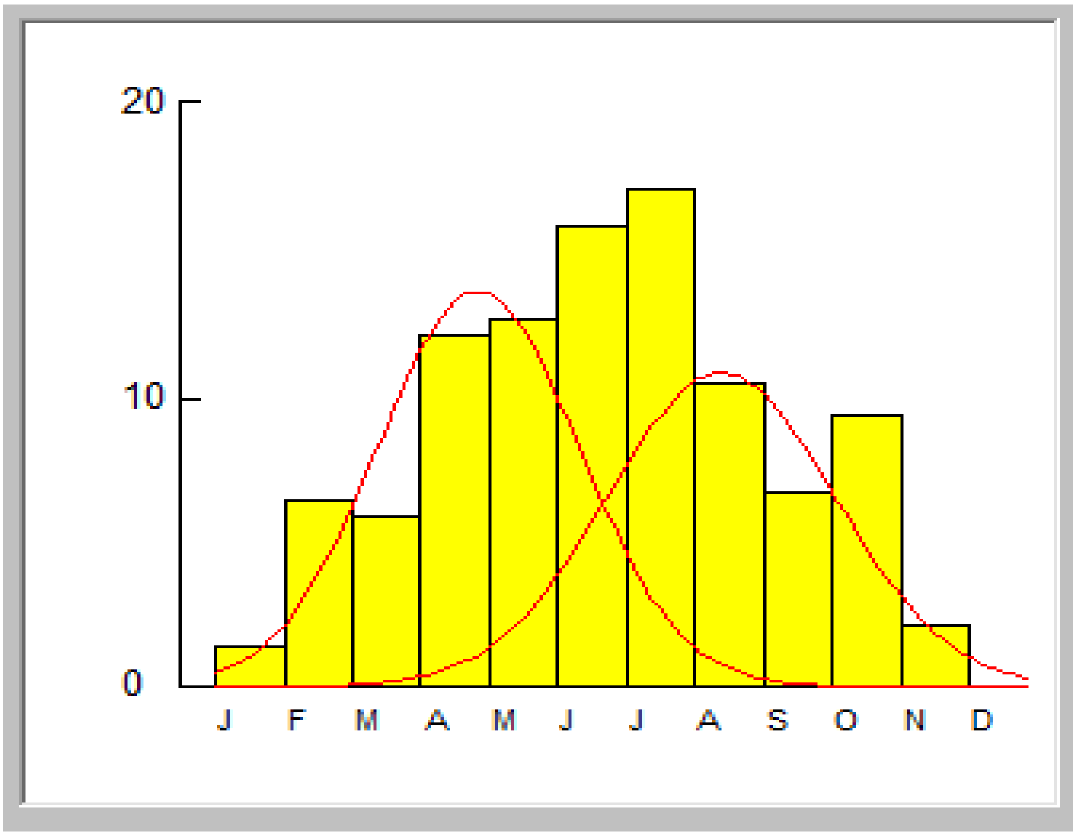

Figure 4.5-11: Recruitment patterns for *L.niloticus* UVN waters (2008-2013)

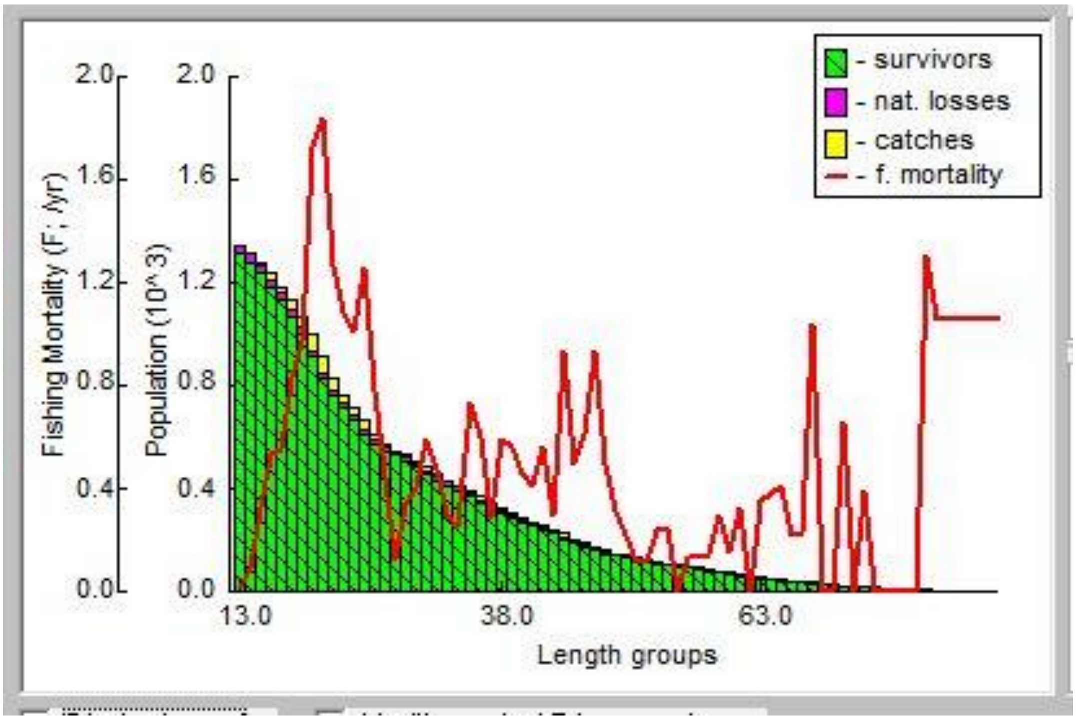

Figure 4.5-12: Length-structures Virtual Population Analysis (VPA) on the *Lates niloticus* indicating the fishing mortality sampled from the Upper Victoria Nile from the experimental data (2014-2019).

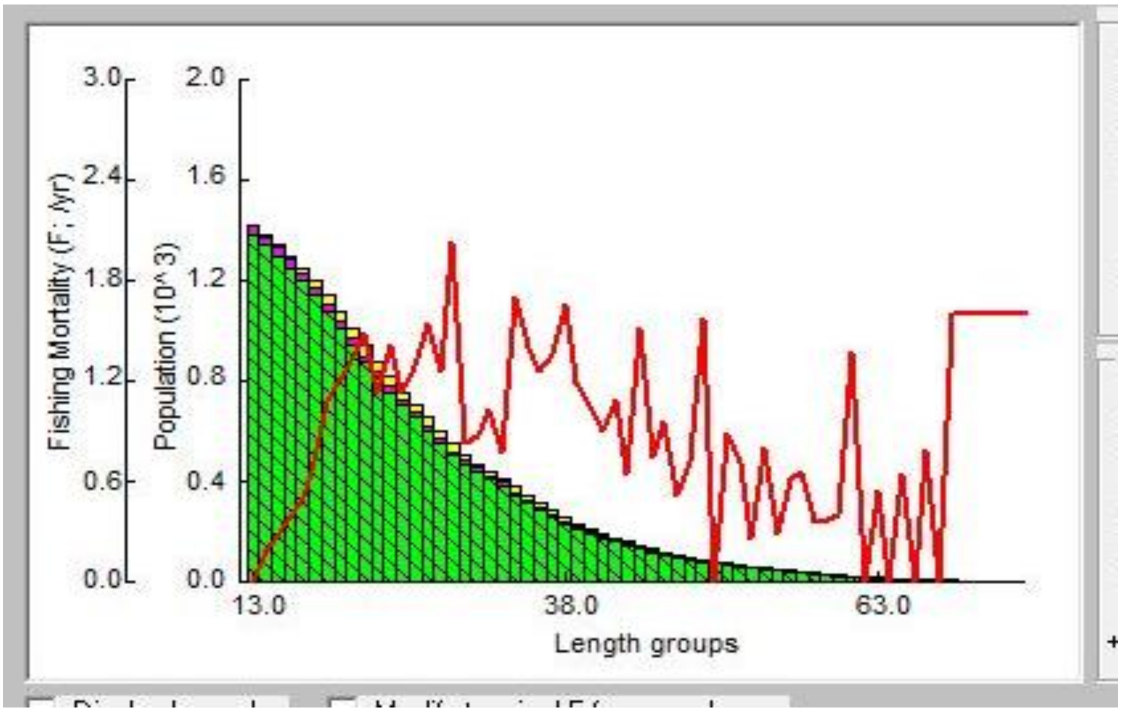

Figure 4.5-13: Length-structures Virtual Population Analysis (VPA) on the *Lates niloticus* indicating the fishing mortality sampled from the Upper Victoria Nile from the experimental data (2008-2013).

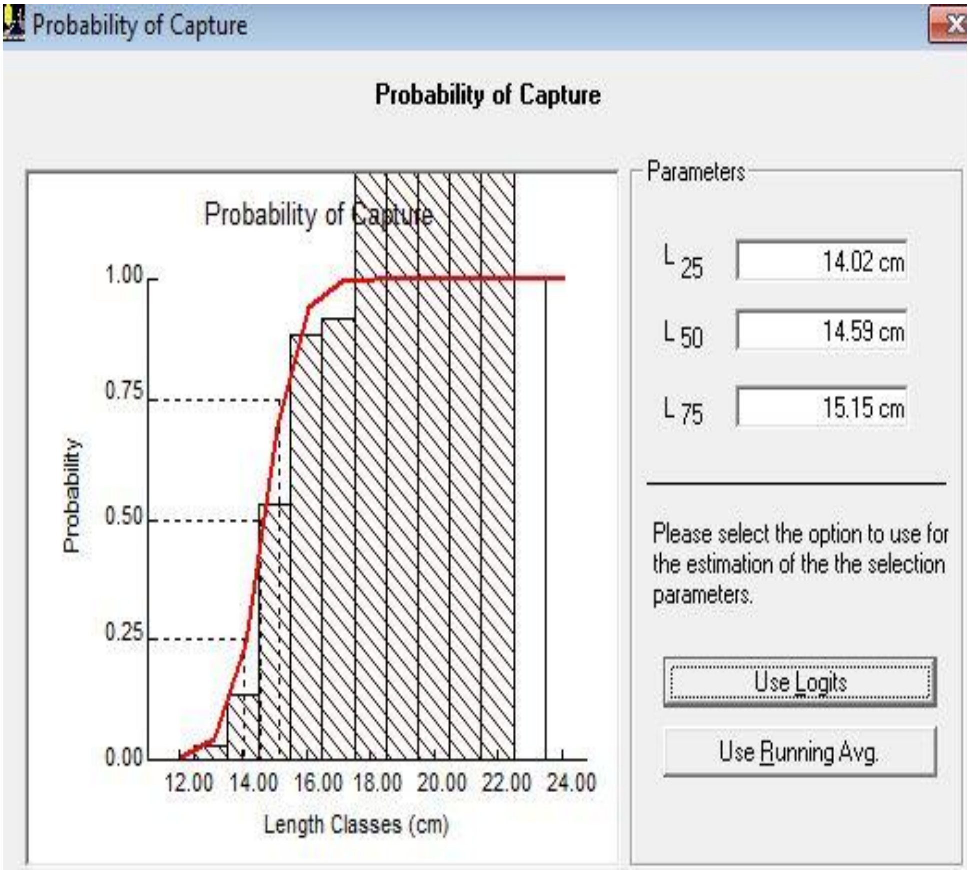

Figure 4.5-14: Logistic curve showing 25%, 50% and 75% capture length (cm TL) of *Lates niloticus* (broken lines) from upper Victoria Nile, Uganda (2014-2019).

The Nile perch sampled in the study showed two peaks recruitment periods, a minor one in June and a major one in August, accounting for 12.8% and 26.3%, respectively. The probability of capture indicated at least 25% of fish of 14.02 cm TL, 50% of the fish of 13.59 cm TL, and 75% of all fish of 15.15 cm TL retained on an encounter with the gear (Figure 4.5-14). This finding wascompared with findings from previous studies that showed two peaks recruitment period, a minor in May and a major in July, accounting for 12.66% and 16.95%, respectively. The probability of capture indicated at least 25% of fish of 12.17 cm TL, 50% of the fish of 13.11 cm TL, and 75% of all fish of 14.03 cm TL retained on the encounter with the gear (Figure 4.5-14).

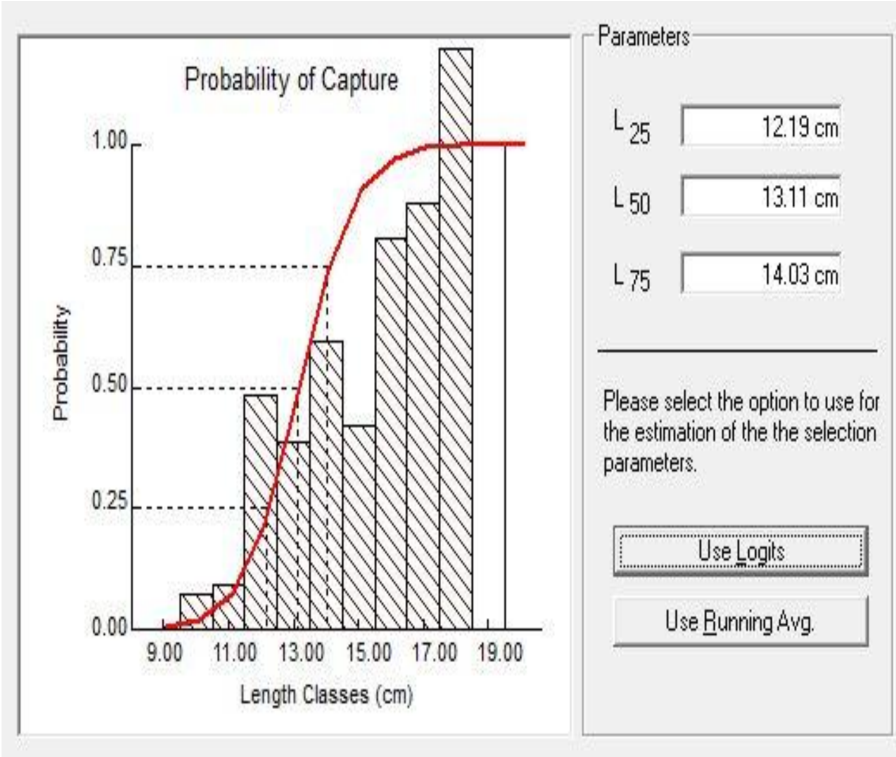

Figure 4.5-15: Logistic curve showing 25%, 50% and 75% capture length (cm TL) of *Lates niloticus* (broken lines) from upper Victoria Nile, Uganda (2008-2013).

4.5.4 Sex Ratios for Nile perch

Seven hundred and five (705) Nile perch samples from UVN were collected from 2014 to 2019. Females were 96, males were 609, constituting a ratio of 2.2:1.6. This ratio was statistically differentfrom the hypothetical 1:1 female to male. Chi-square test showed (X^2= 159.184, df =1, P<0.05) .A comparison with the previous studies indicated that eight hundred andseventy-six (876) Nile perch samples from UVN were collected. Females were 86, males were 442, and the rest were immature, constituting a ratio of 1.4:1. This ratio was statistically differentfrom the hypothetical 1:1 female to male. Chi-square test showed males (X^2=517.416, df=1, P<0.05).

4.6.4 Size Structure for Nile perch

The length-frequency data showed that most of the fishes harvested were below the length of the first maturity. The size of the first maturity for Nile perch in the sampled period showed that the females were 30.0 cm TL and 40.3 cm TL (Figure 4.5-10). The variation in size structure showed a decline in the temporal trends, as indicated in Figure 4.5-1.

4.6.5 Food and Feeding Interactions of Nile perch

Eleven (11) food types were recorded from the gut contents of the Nile perch in the UVN (Table 4.5-1). These food materials included Fish remains, *Caridina niloticus,* haplochromines, *Rastrineobola argentae*, Hydrocinus, Povilla, Chironomids, Tricoptera, Insect remains and Barbus species. The juveniles ranged from 7.4-18.5 cm TL.The highest percentage fed on *Caridina niloticus, Rastrineobola argentae* and fish remains. While those from 19.0-64.0 cm TL fed on haplochromines, *Barbus* species, fish remain and *Caridina niloticus.*

Table 4.5-1: Gut contents for the Nile perch

Length range Total length (cm)	Food contents	Percentage Contribution	Chi-square tests
19.0-64.0 cm TL	Haplochromines	13.2	(X^2=60.21;df=4:P<0.05)
	Barbus	1.3	(X^2=0.0001df=4:P>0.05)
	Hydrocinus	6.6	(X^2=3.600;df=3:P>0.05)
	Fish remains	17.9	(X^2=109.220;df=9:P<0.05)
	Caridina nilotica	54.3	(X^2=0.000, df =4, P>0.05)
	Odonata	4.6	(X^2=0.857;df=2:P>0.05)
	Trichopteran	1.9	(X^2=0.333;df=1:P>0.05)
7.0-18.5 cm TL	R.argentae	9.2	(X^2=19.913, df =6, P<0.05)
	Hydrocinus	1.6	(X^2=0.50, df =2, P>0.05)
	Fish remain	13.9	(X^2=40.400, df =6, P<0.05)
	Caridina nilotica	4.4	(X^2=4.8180, df =5, P<0.05)
	Odonata	0.8	(X^2=0.00, df =1, P>0.05)
	Insect remains	0.8	(X^2=0.000, df =1, P>0.05)

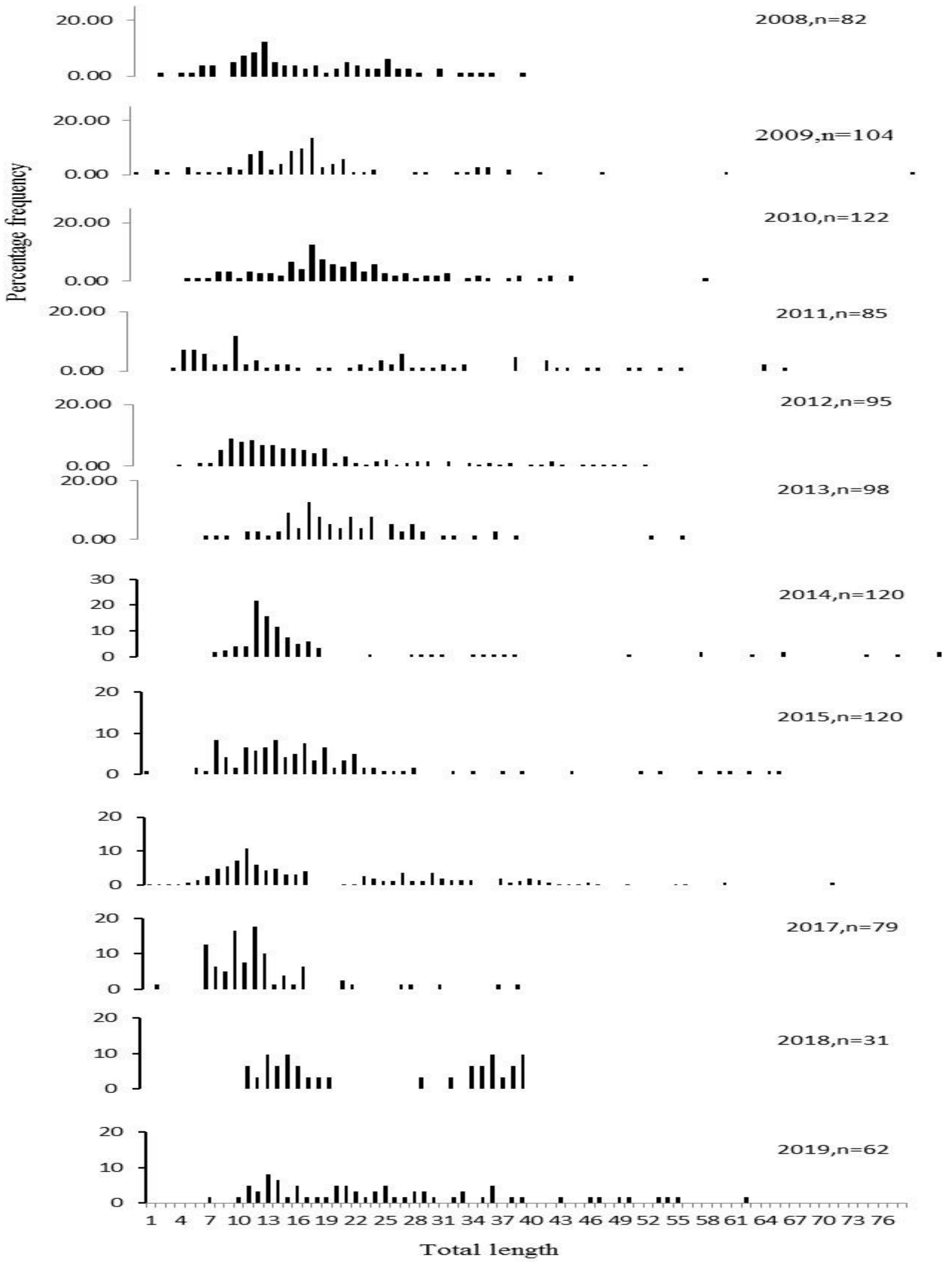

Figure 4.5-1: Size structure for Nile perch from the CAS data UVN.

4.7 The Nile tilapia, *Oreochromis niloticus* growth and mortality parameters in the UVN

4.7.1. Length –Weight Relationship of Nile Tilapia *Oreochromis niloticus*

One hundred and sixty-eight (168) specimen of *O. niloticus* from experimental gillnet were used in developing its length-weight relationship. The total length of the fish caught ranged from 7.5 to 38 cm (TL), while the total weight ranged from 7.5 to 1,300 grams. The average length and weight were 19.42 (±3.1) cm TL while the mean weight was 228.05 (±22.97) g (TW). Length-weight relationship indicated that b value was 3.0896 and a= 0.01373 with R^2 of 0.9729 (Figure 4.6-2).The length-weight relationship depicted that growth in Nile tilapia is isometric; its growth in weight and length is proportional. The relationship is indicated (Figure 4.6-2).

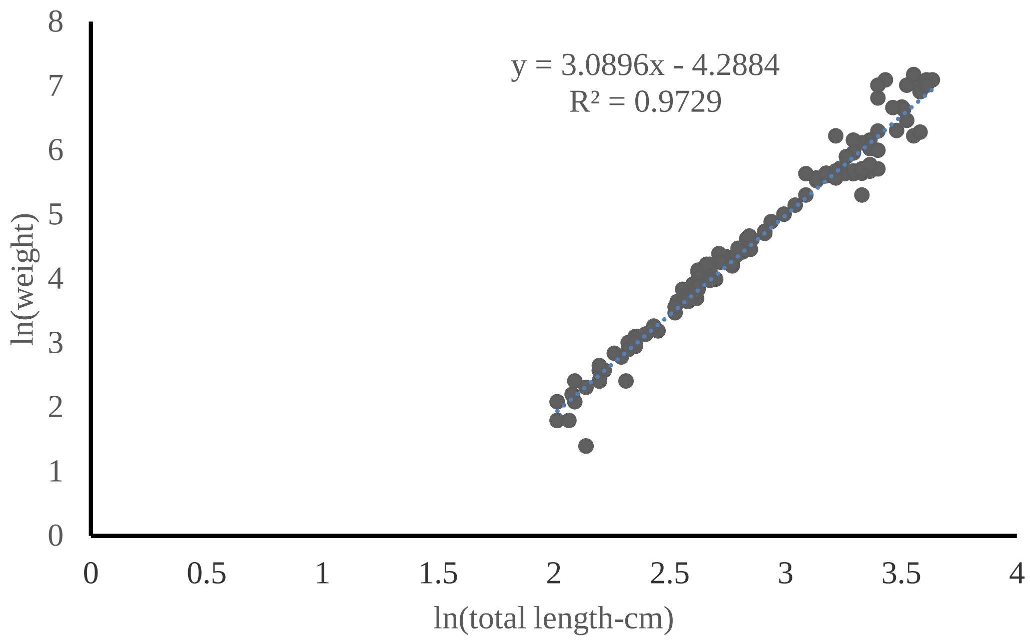

Figure 4.6-2: Length-weight relationship for *O.niloticus*in the UVN waters

ANOVA test obtained showed that ($F= 5952.92$, $df =167$, $P<0.05$. The results were compared with the previous studies that showed: $a=0.085983$, $b=3.0$, $R^2=0.7749$ and ANOVA test ($F= 265.04$, $df=78$, $P<0.05$).

4.7.2 Growth Parameters of *O. niloticus*

The output of the ELEFAN method for estimating the *Oreochromis niloticus* growth parameters is presented in (Figure 4.6-3, 4.6-4).The von Bertalanffy growth parameters of *O. niloticus* were estimated as $L_\infty=47.25$, (TL cm) and growth coefficient K=0.890 per year. The t_o value (time in years at the time of birth) was calculated by Pauly's equation denoted as

$l_t=L_\infty=(1-\exp(-k(t-t_o)))$.

The value of the time is the hypothetical age $t_o= -0.7517$ when length of the virtual age is considered zero. The value of t_o was estimated by the Pauly's empirical formula denoted as :

$Log_{10}(-t_o) =0.3922-0.275Log_{10}L_\infty-1.028Log_{10}K$ per year.

R_n (goodness of fit) was estimated to be at 0.136 with ELEFAN-1 method. The longevity t maximum was estimated as at $t_{max}=4.13$ years as the maximum age for the species recorded for the whole sampling period. The growth performance indices based on asymptotic length (L_∞) and (W_∞) were ØL= 3.298per year and ØW= 2.079 per year recorded for the *O. niloticus*species from the riverine of the UVN waters. Compared with previous studies of 2008 to 2013, the current study outputs obtained the following; L_∞ =45.15 (TL cm) and growth coefficient K=0.930 per year, t_o=-0.09523.The longevity t, max was estimated as at t_{max}= 3.3 years.

4.7.3 Mortality Estimates of *O. niloticus*

The total mortality rate (Z) of *O. niloticus* was estimated using the catch curve analysis the total mortality estimated $Z=2.80\ yr^{-1}$ was estimated at 95% confidence interval (CL= 2.11-

3.48). The value of natural mortality (M) estimated from Pauly's formulae was M=1.41 yr^{-1} using the riverine surface temperature of (RST) 26°C. Thus, the fishing mortality was calculated as F=Z-M=1.39yr^{-} and exploitation ratio (E) was calculated from F/Z= 0.4964. The recruitment pattern indicated the yield per recruit of *O. niloticus* parameters as follows; Lc/L_∞=0.050, M/K=1.58427. The exploitation rate at 10% was 0.308 and at 50% was 0.250 and E_{max}=0.383 and B/Y of 0.50, Y/R of 0.03. These outputs were compared with the results from 2008 to 2013 which showed that Z=3.22, M=1.47, F=1.75, E=0.54 yield/recruit=, (E0.1) =0.309, (E0.5) =0.250, (E_{max}) = 0.2383 and Y/R=0.03 grams, t_{max}=3.3 years and t_o=-0.09523. (Figures 4.6-5, 4.6-6, 4.6-7, 4.6-8, 4.6-9, 4.6-13, and 4.6-14).

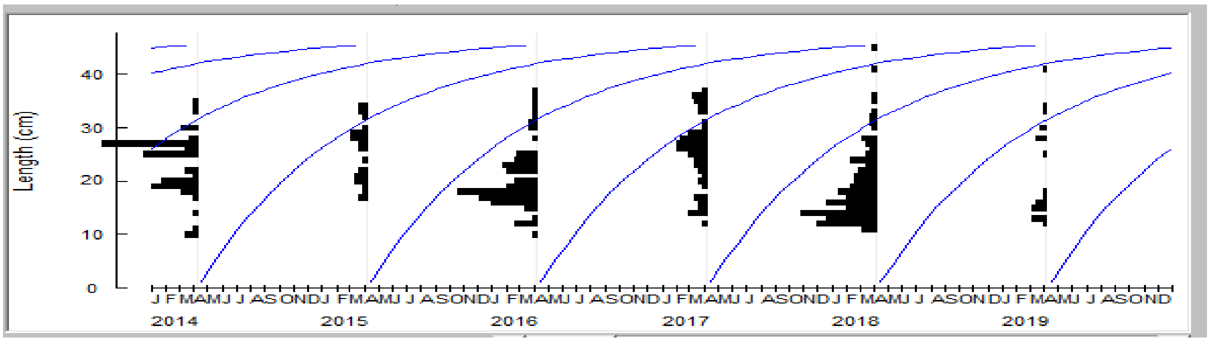

Figure 4.6-3: Total length, von Bertalanffy growth curve for *O.niloticus* in the UVN 2014-2019

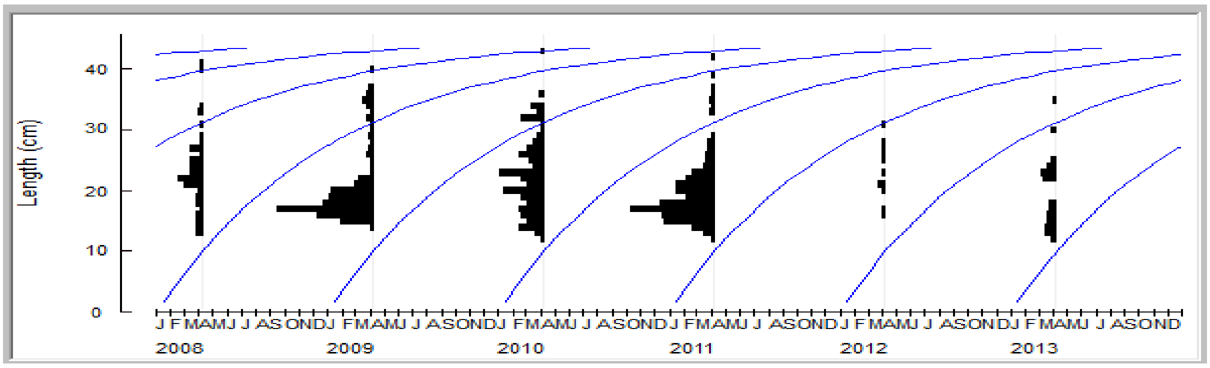

Figure 4.6-4: Total length, von Bertalanffy growth curve for *O.niloticus* in the UVN 2008-2013

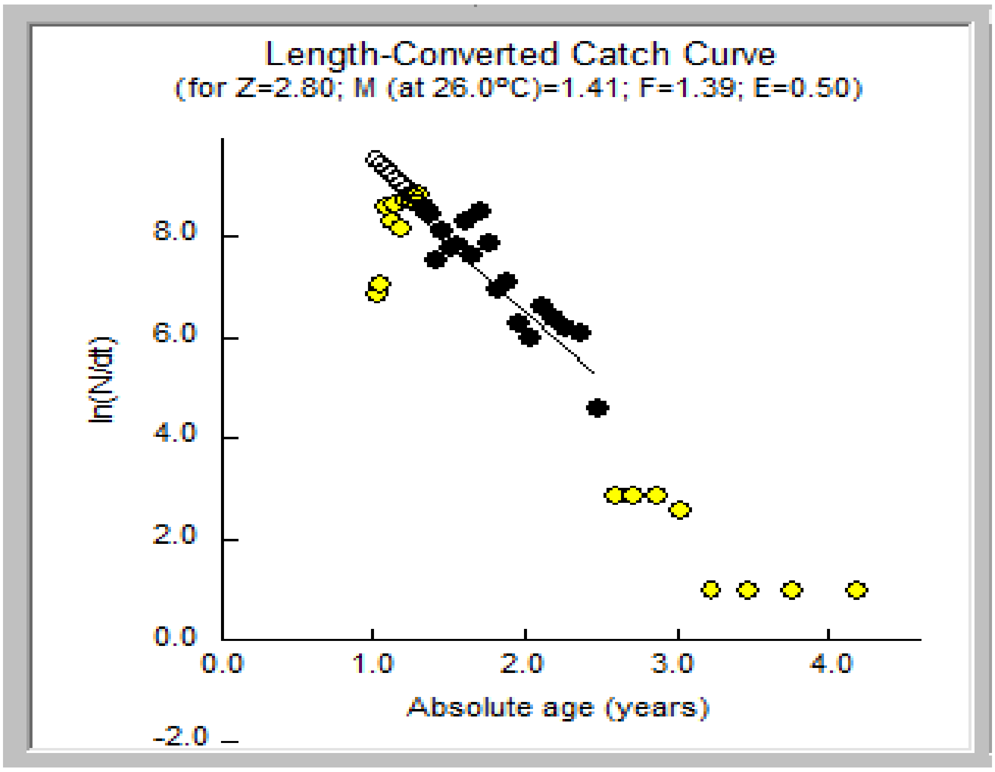

Figure 4.6-5: The growth parameters for *O. niloticus* sampled 2014-2019

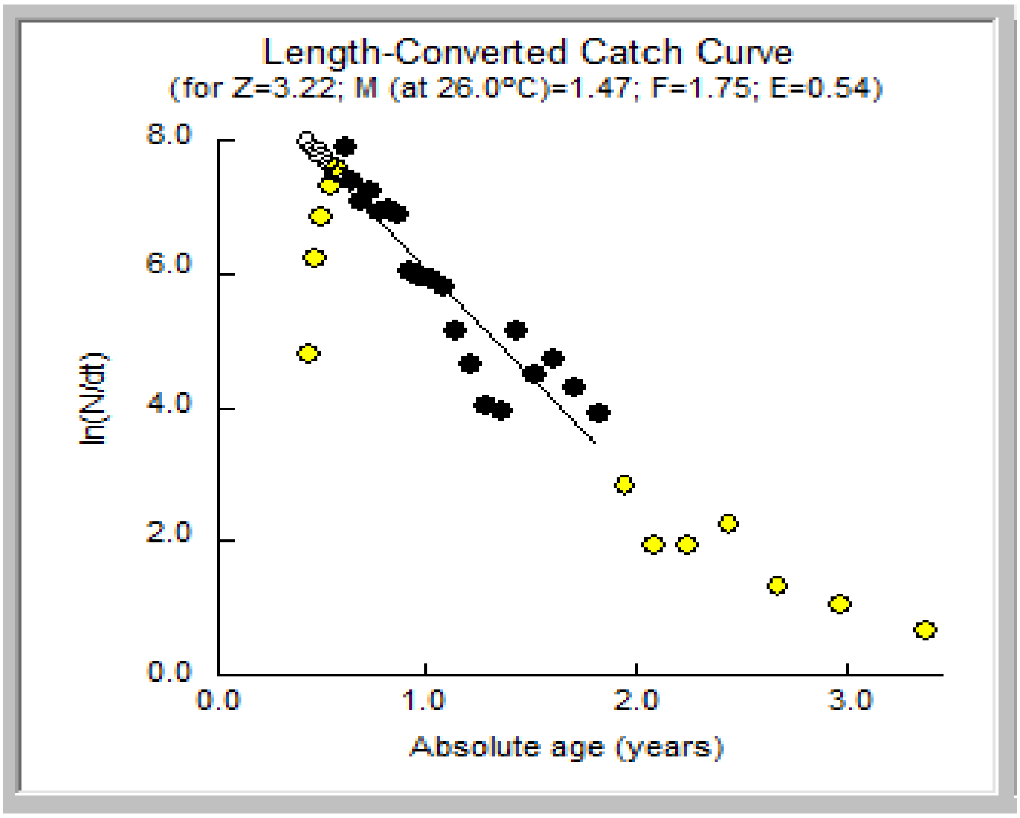

Figure 4.6-6: The growth parameters for *O. niloticus*(2008-2013).

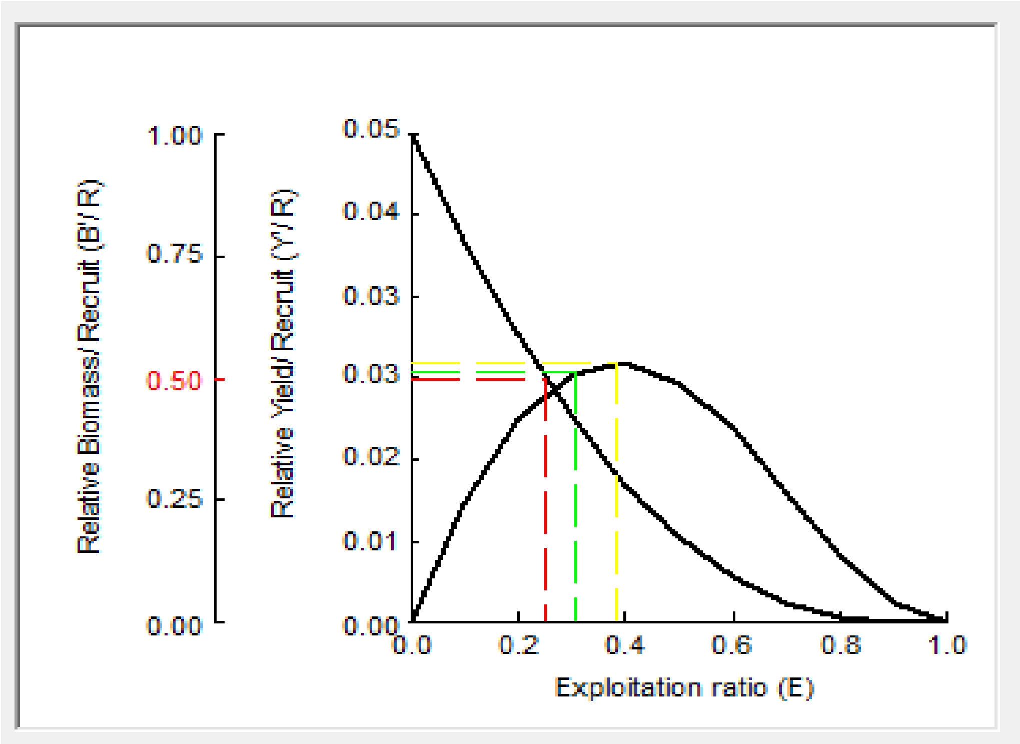

Figure 4.6-7: Indicates the yield per recruit analysis (knife–edge selection Isopleth) the Exploitation rate of the *O. niloticus* from the experimental data sampled in the Upper Victoria Nile 2014-2019

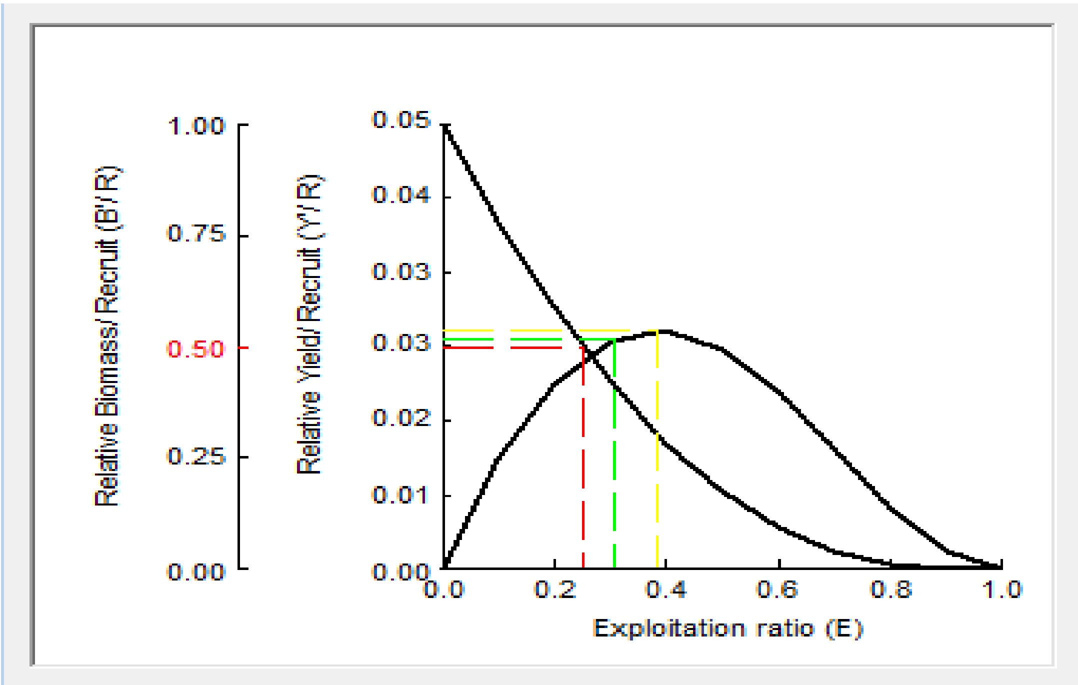

Figure 4.6-8: Indicates the yield per recruit analysis (knife–edge selection Isopleth) the Exploitation rate of the *O. niloticus* from the experimental data sampled in the Upper Victoria Nile 2008-2013

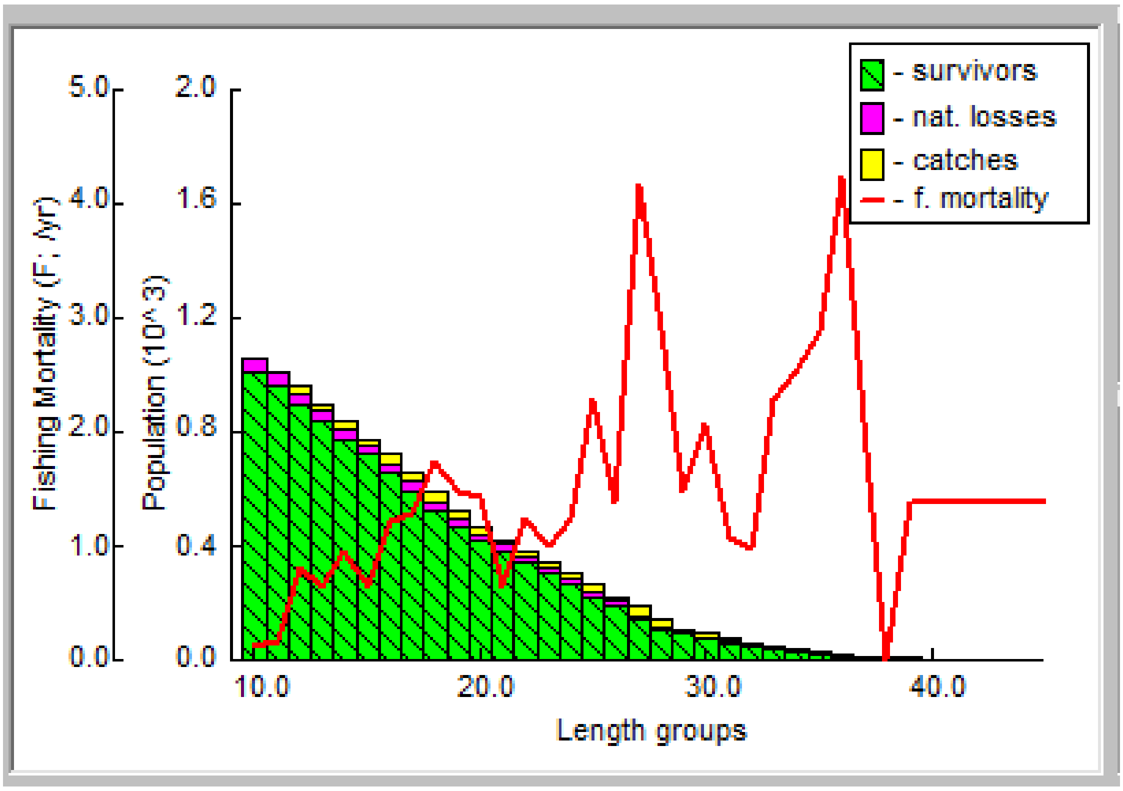

Figure 4.6-9: Length-structures, Virtual Population Analysis (VPA) on the *Oreochromis niloticus* indicating the fishing mortality (F=1.39) sampled from the Upper Victoria Nile from the experimental data 2014-2019

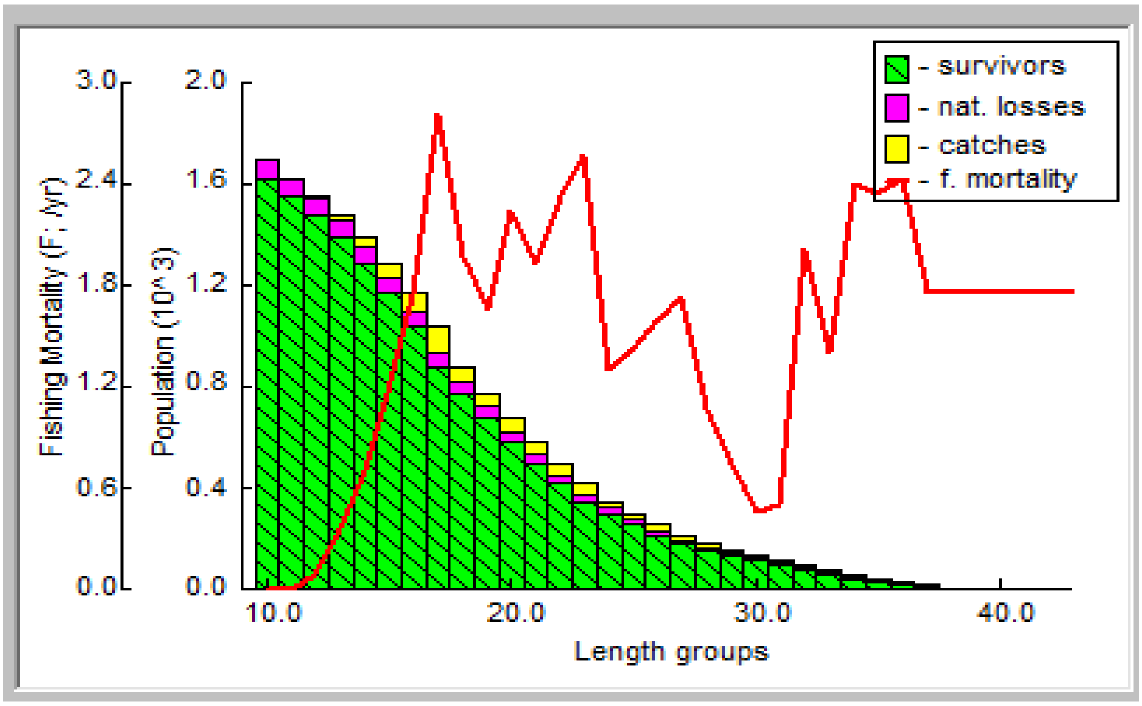

Figure 4.6-10: Length-structures Virtual Population Analysis (VPA) on the *Oreochromis niloticus* indicating the fishing mortality (F=1.39) sampled from the Upper Victoria Nile from the experimental data 2008-2013.

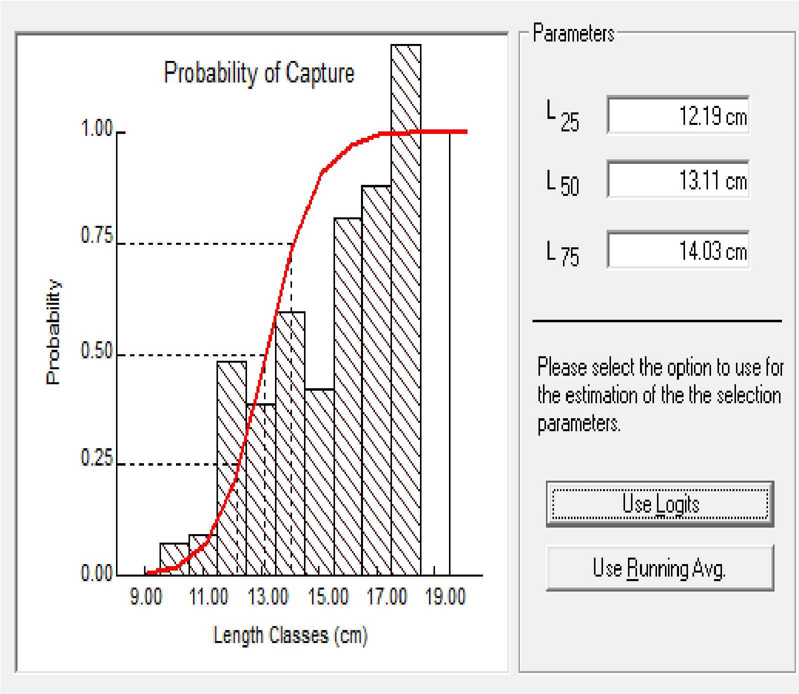

Figure 4.6-11: Logistic curve showing 25%, 50% and 75% capture length (cm TL) of *Oreochromis niloticus* (broken lines) from upper Victoria Nile, Uganda 2014-2019

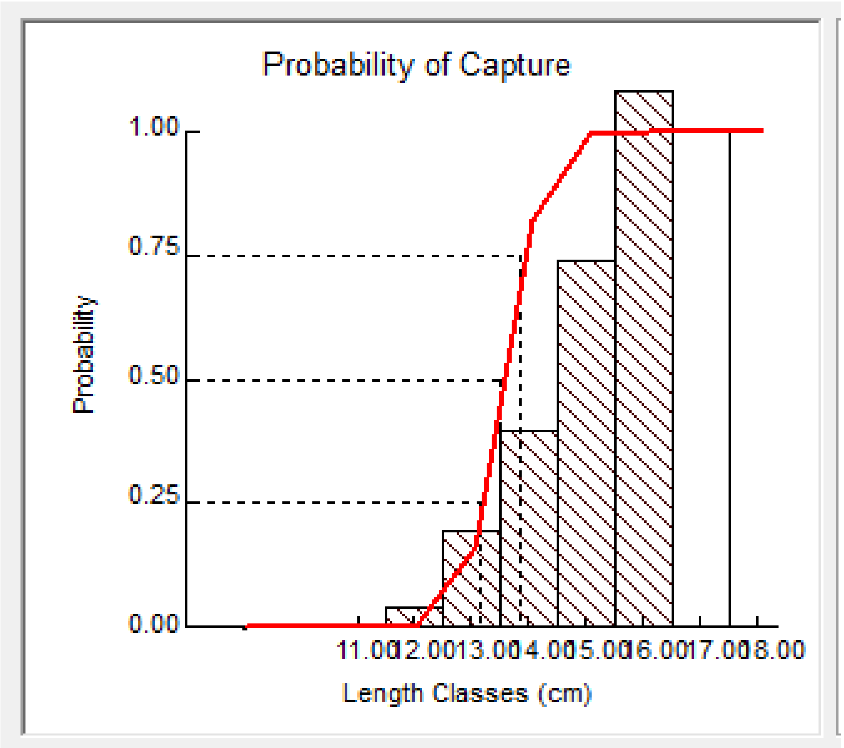

Figure 4.6-12: Logistic curve showing 25%, 50% and 75% capture length (cm TL) of *Oreochromis niloticus* (broken lines) from upper Victoria Nile, Uganda 2008-2013

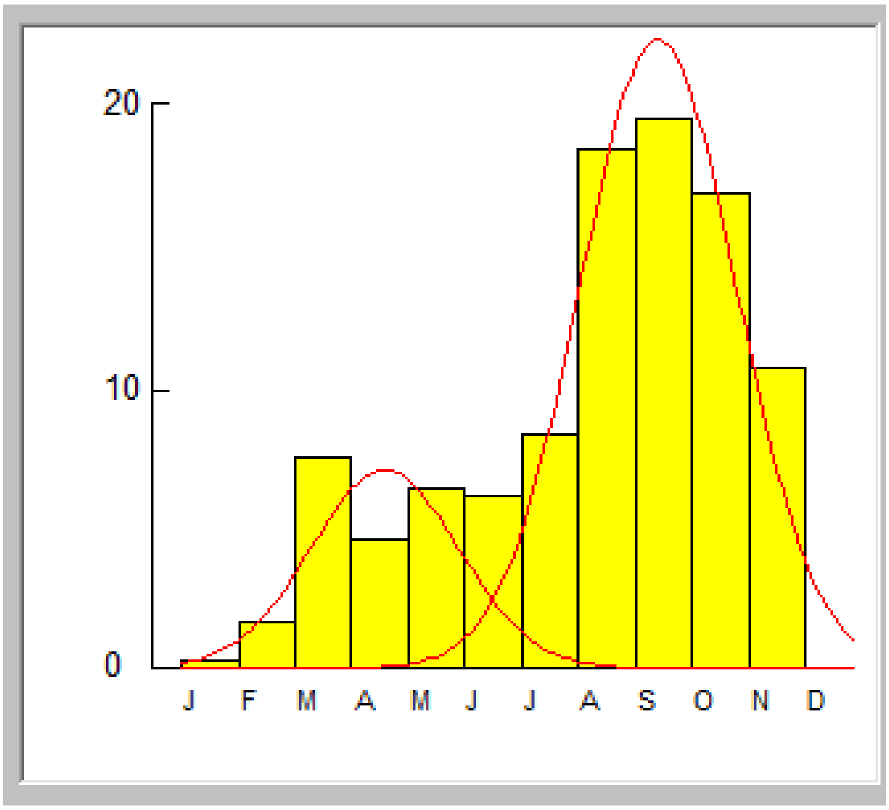

Figure 4.6-13: Recruitment patterns for *O.niloticus*in the UVN waters (2014-2019)

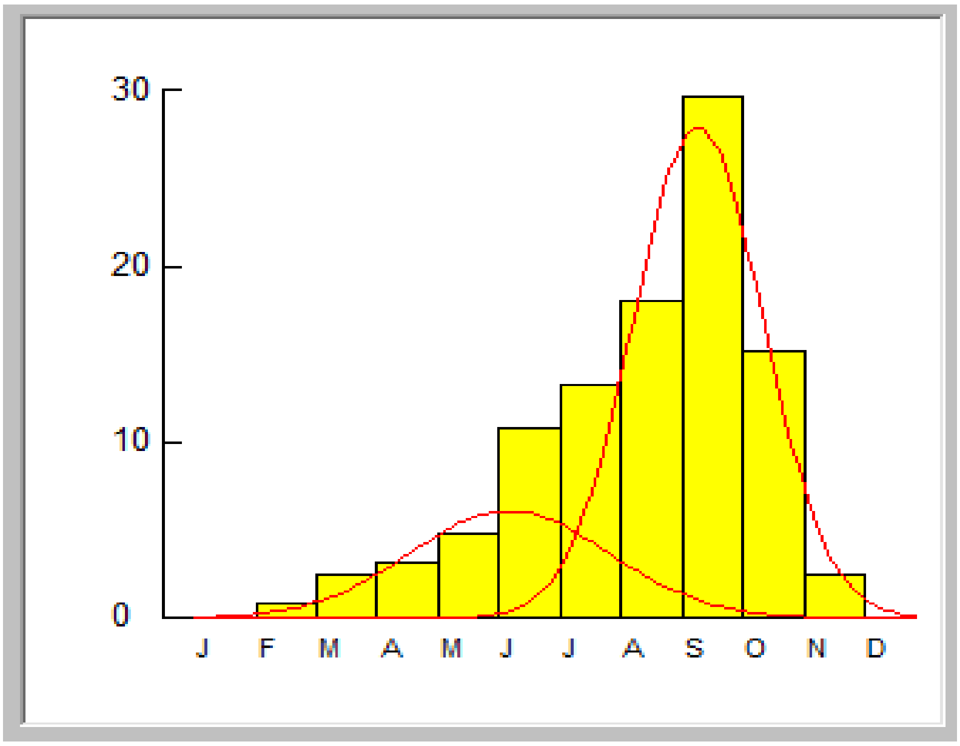

Figure 4.6-14: Recruitment patterns for *O.niloticus*in the UVN waters (2008-2013)

The probability of capture indicated that at least 25% of fish of 12.19 cm TL, 50% of the fish of 13.11 cm TL, and 75% of all fish of 14.03 cm TL were retained on the encounter with the gear (Figure 4.6-11). A comparison with the previous study in the same ecosystem from 2008 to 2013 showed two peaks recruitment periods, a minor in June and a major in September, accounting for 10.86% and 29.62%, respectively. The probability of capture indicated that at least 25% of fish of 13.17 cm TL, 50% of the fish of 13.52 cm TL, and 75% of all fish of 13.87 cm TL were retained on the encounter with the gear (Figure 4.6-12).

4.7.4 Sex Ratios for *Oreochromis niloticus*, Nile tilapia

One hundred and sixty-nine (169) Nile tilapia samples from UVN were collected from 2014 to 2019. Females were 48, males were 101, and the rest were immature, constituting a ratio of 1.1:1. This ratio was significantly different from the hypothetical 1:1 female to males. Chi-square test showed (X^2=30.857, df =1, $P<0.05$). The previous studies indicated that seventy-nine (79) Nile tilapia samples from UVN were collected. Females were 27, males were 52, and the rest were immature, constituting a ratio of 1:1.9. This ratio was not significantly different from the hypothetical 1:1 female to male. Chi-square test showed (X^2=7.911, df =1, $P<0.05$).

4.7.5 Size Structure for Nile tilapia

The length frequency data showed that most of the fishes harvested in the UVN showed smaller sizes compared to the Victoria tilapiines, a sign that these fishes were maturing at an early stage than expected (Figure 4.7-1).

4.7.6 Food and Feeding Interactions of Nile Tilapia

Fourteen (14) food types were recorded from the gut contents of the Nile tilapia in the UVN (Table 4.6-1). These food materials included Fish remains, Povilla, Chironomids, Molluscs, Insect remains, High plant materials, Zooplanktons, Detritus, Blue Green algae, Green algae, Diatoms, Euglena and Ostracodes. Chi-square test obtained the following.

Table 4.6-1: Gut contents for the Nile tilapia (N/A- not applicable)

Food contents	Percentage contribution	Chi-square tests
Fish remains	2.2	(X^2=28.140, df =5, P<0.05
Povilla	2.2	N/A
Chironomids	2.2	N/A
Molluscs	2.2	N/A
Insect remains	11.1	(X^2=0.000, df =4, P>0.05)
High plant materials	13.1	(X^2=0.000, df =5, P>0.05)
Zooplanktons	2.2	N/A
Detritus	20	(X^2=1.111, df =6, P>0.05)
Blue Green algae	11.1	(X^2=0.000, df =4, P>0.05)
Green algae	17.7	(X^2=0.000, df =7, P>0.05)
Diatoms	11.1	(X^2=0.000, df =4, P>0.05)
Euglena	2.2	N/A
Ostracodes	2.2	N/A

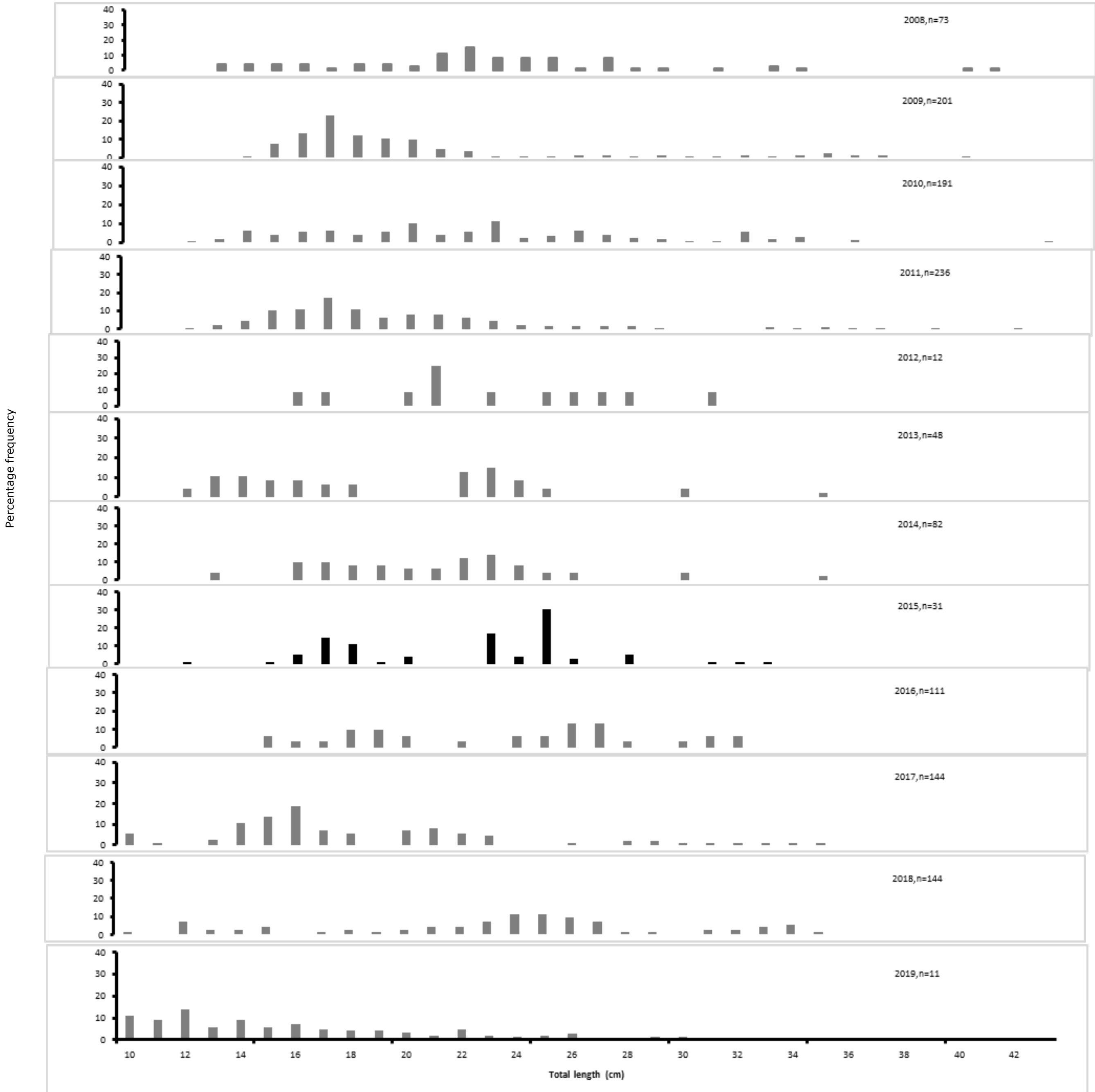

Figure 4.7-1: Size structure for Nile tilapia from the CAS data UVN

4.8 The population parameters of Victoria tilapia, *Oreochromis variabilis*

4.8.1 Length-Weight Relationship for *O. variabilis*

The length ranged from 10 to 31 cm (Total length-TL). The average length and weight were 20.67±0.404 and 0.23±0.012 respectively. The length-weight relationship was calculated as $W=0.0202L^{3.017}$ (R^2= 0.9125) anddepicted that growth in *O. variabilis* is isometric; its growth in weight and length is proportionate (Figure 4.7-2).

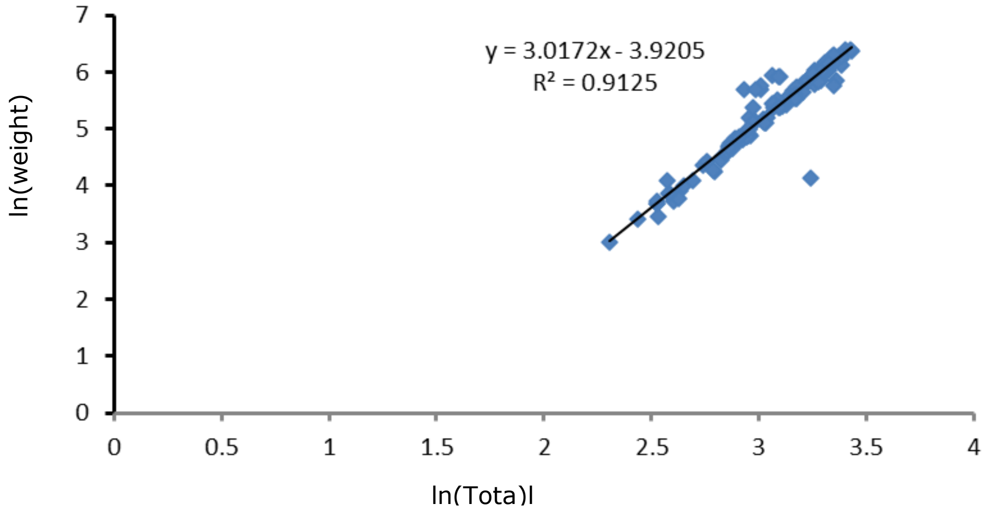

Figure 4.7-2: O*reochromis variabilis* length-weight relationship

Regression analysis indicated, ANOVA test obtained, ANOVA test recorded a significant difference of ($F= 3990.5$, $df=63$, $P<0.05$). The results were compared with findings s from 2008 to 2013 which indicated that: $a=0.0848$, $b=3.29795$, $R^2=0.9847$ and ANOVA test showed a significant difference of ($F= 1241.2$, $df =120$, $P<0.05$).

4.8.2 Growth Parameters of *Oreochromis variabilis*

The output of the ELEFAN method for estimating growth parameters for *Oreochromis variabilis* is presented in Figures 4.7-7.The von Bertalanffy growth parameters of *O. variabilis* were estimated as L_∞ = 36.75(TL cm) and growth coefficient K=0.44 per year. The t_o value (time in years at the time of birth) was calculated by Pauly's equation denoted as: $l_t=L_\infty= (1-\exp(-k(t-t_o)))$ The value of the time t_o is the hypothetical age $t_o= -0.4540$ when the length of the virtual age is considered zero. Value of t_o was estimated by Pauly's empirical formula denoted as $Log_{10}(-t_o) =0.3922-0.275Log_{10}L_\infty-1.028Log_{10}K$ per year. The longevity t_{max}, was estimated at $t_{max}= 6.4$ years as the maximum age for the species recorded for the whole sampling period.

The growth performance indicesfor *O.variabilis* from the riverine of the UVN waters based on asymptotic length (L_∞) and asymptotic weight (W_∞) were Ø'= 2.774per year and Ø= -0.301 per year

4.8.3 Mortality estimates of *O. variabilis*

The total mortality estimated using a catch curve analysis asZ=1.74 yr^{-1}. The value of natural mortality (M) estimated from Pauly's formulae was M=0.95 yr^{-1} using riverine surface temperature of (RST) 26°C. Thus, the fishing mortality was calculated as:F=Z-M=0.79 $yr^{-1}$and exploitation ratio (E) was calculated from F/Z=0.4504 and Lc/L_∞=0.5905 M/K=2.15901 (Figures 4.7-3). The application of von Bertalanffy growth curve on the size structure recorded decreasing trends in the size structure over time and space. The recruitment patterns recorded months of March (13.50%) and August (12.66%) (Figure 4.7-4).

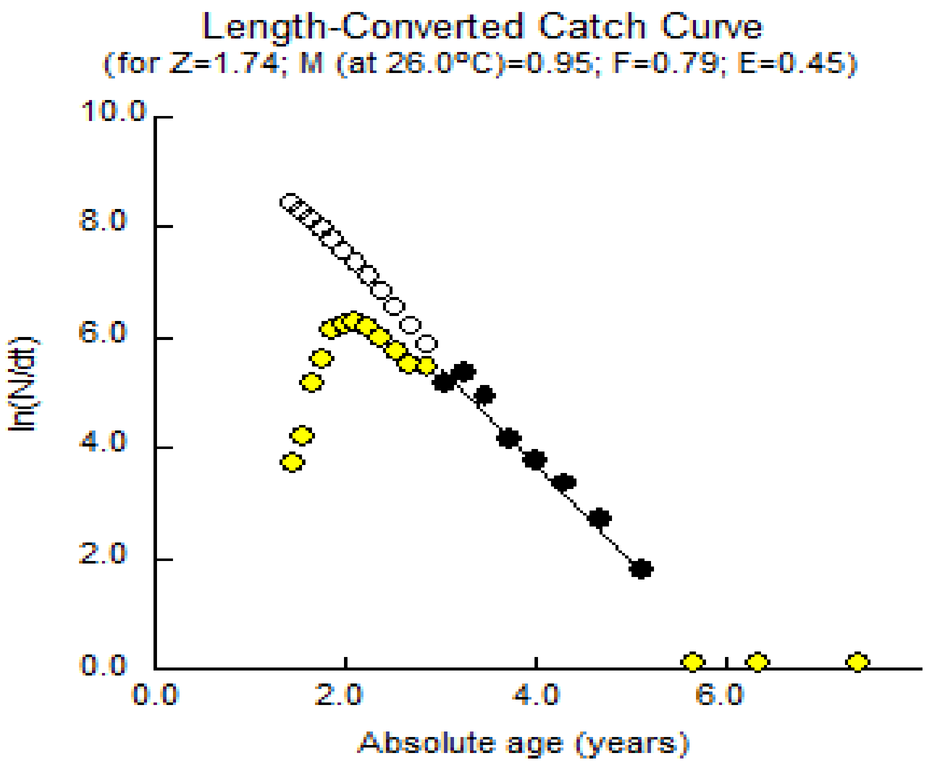

Figure 4.7-3: The mortality rates for *Oreochromisvariabilis* from the UVN (2014-2019)

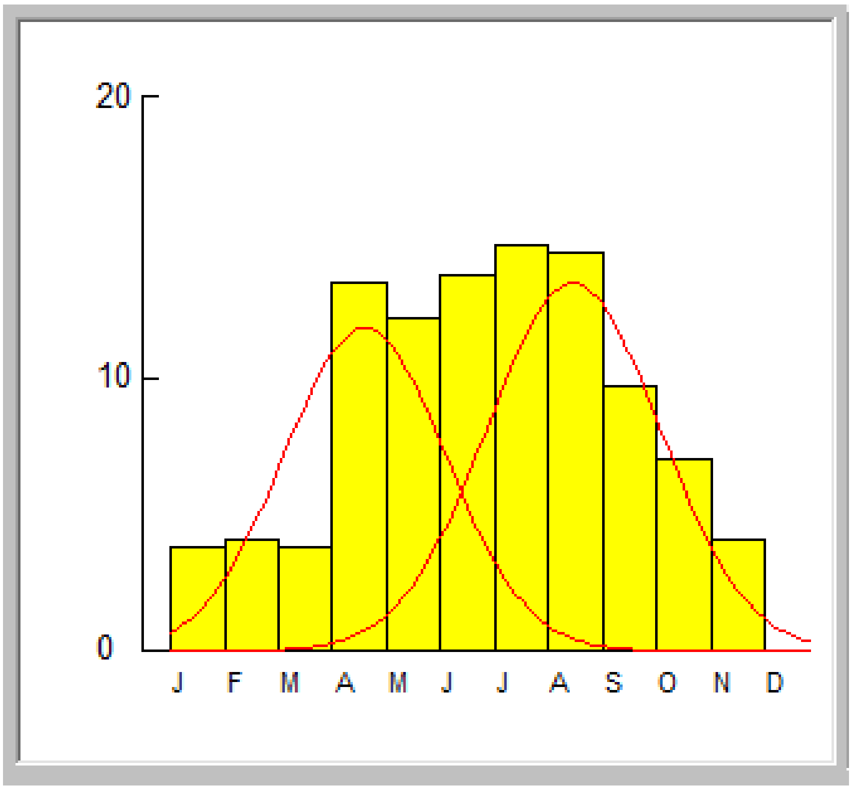

Figure 4.7-4: The Recruitment patterns for *Oreochromisvariabilis* from the UVN with patterns of the two-year circle (2014-2019)

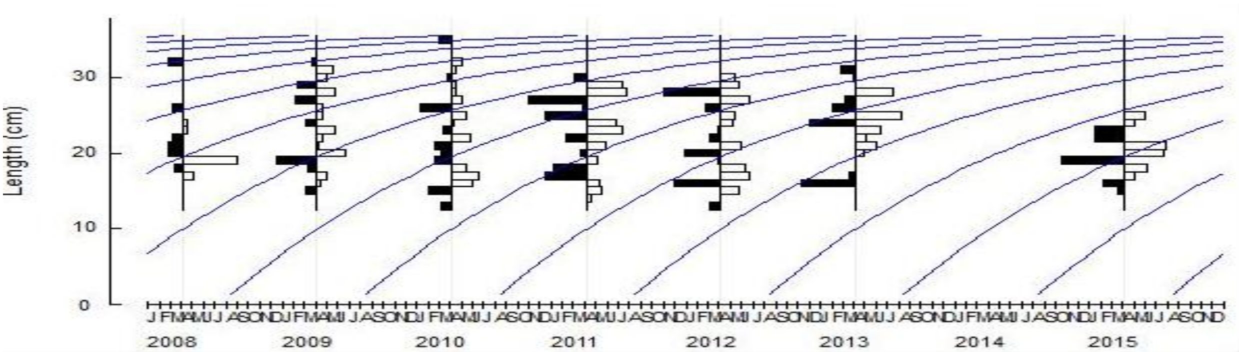

Figure 4.7-5: The Total length, von Bertalanffy growth curve for *Oreochromis variabilis* from the UVN

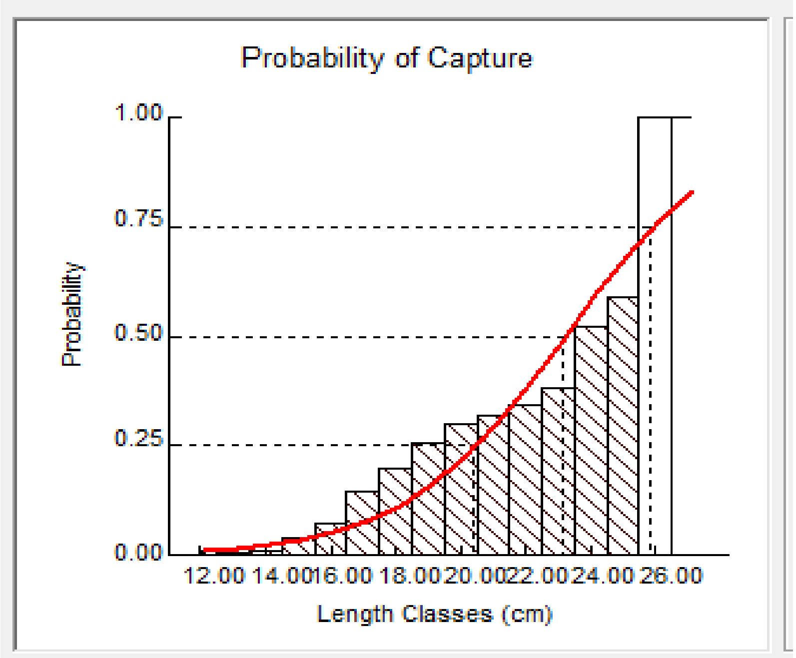

Figure 4.7-6: Probability of capture of *O. variabilis* in centimetres Total length sampled from UVN

The probability of capture indicated at least 25% of fish of 20.39 cm TL, 50% of the fish of 23.11 cm TL and 75% of all fish of 25.84 cm TL retained on the encounter with the gear (Figure 4.7-6). There were two peaks recruitment period, a minor in April and a major in July, accounting for 13.22% and 14.57% respectively.

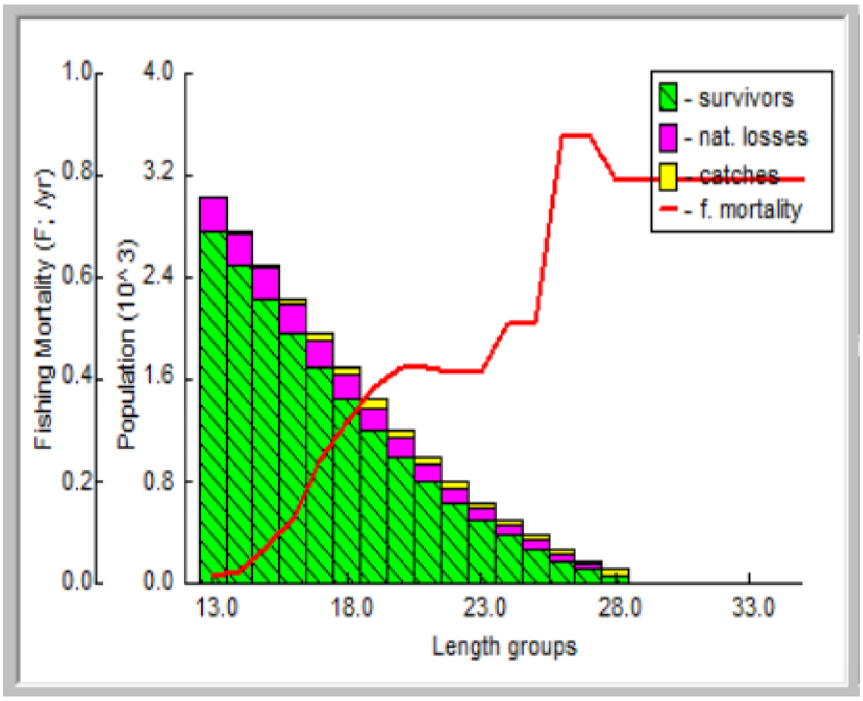

Figure 4.7-7: Length-structures Virtual Population analysis (VPA) on the *O.variabilis* for the experimental data in the UVN.

4.8.5 Sex Ratios for Victoria Tilapia *(O. variabilis)*

Sixty-three (63) Nile tilapia samples were collected from UVN. Females were 70, males were 51, constituting a ratio of 1:1.1 This ratio was significantly different from the hypothetical 1:1 female to males' ratio. Chi-square test indicated (X^2=0.016, df=1, P<0.05) in 2014- 2019.

Then in 2008-2013, one hundred and twenty-one (121) Nile tilapia samples were collected from UVN. Females were 70, males were 51, constituting a ratio of 1.1:2.1. This ratio was significantly different from the hypothetical 1:1 female to males' ratio. Chi-square test indicated (X^2=0.000 df=1, P<0.05).

4.8.6 Food and Feeding Habits of *O. variabilis*

Eleven (11) food types were identified from the gut contents of the *O. variabilis* species. Some of the types included Macroinvertebrates like Trichopteran, Hemiptera, Rotifers, Copepods, Chaobrus larvae, Crabs and Insectremains. There were other food types such as Detritus, Blue green algae, green algae and Diatoms. Fish depended on the following food types: - Chaobrus larvae 4.08%, Trichopteran 4.08%, Insect remains 6.12%, Hemiptera 4.08%, Crabs 4.08%, Detritus 6.12%, Blue green 22.45%, Green 20.41%, Diatoms 14.29%, Copepods 4.08% and Rotifers 4.08%.

The Chi-square (X^2) test was used to tests for significant differences in the diet within and between periods of sampling. These food types were-

Chaobrus larvae, (F=0.45; df=1;P>0.05),Trichopteran (F=1.0; df=1;P<0.05), Insect remains (F=0.89;df=1; P>0.05), Hemiptera (F=0.8; df=2;P>0.05), Crabs (F=1.0; df=2;P<0.05),Detritus (F=0.9; df=10;P>0.05), Blue green algae (F=1.0;df=10 P<0.05), Green algae (F=1.0;df=7; P<0.05), Diatoms (F=0.99;df=7P>0.05).

4.9.0 Trends in Fishing Effort and Fish Catches in the Upper Victoria Nile

4.9.1 Fishing effort variations from UVN

The UVN had two boat types such as parachute and Ssese flat pointed one end that were used by fishers in this ecosystem The catch effort data from UVN obtained nine hundred and ninety three (993) Ssese flatboats during the period of 2014-2019 compared to three hundred and ninety nine (399) in 2008 to 2013 (Figure 4.8-1). Parachute were 17 boats, from 2014 to2019 compared to 38 boats in the 2008 to 2013 period (Figure 4.8-2; Plate 4.8-1). In the reference periods, 13-foot fishers were obtained against 13 respectively.

Then with boat gear combination, Traps obtained 30% followed by hook and line 22% and the least was monofilament boat type with 0.10% in the period of 2014-2019. In 2008-2013, Hook and line was 20.5% followed by 19.5% and the least was boat seines with 0.41% (Figure 4.8-3).

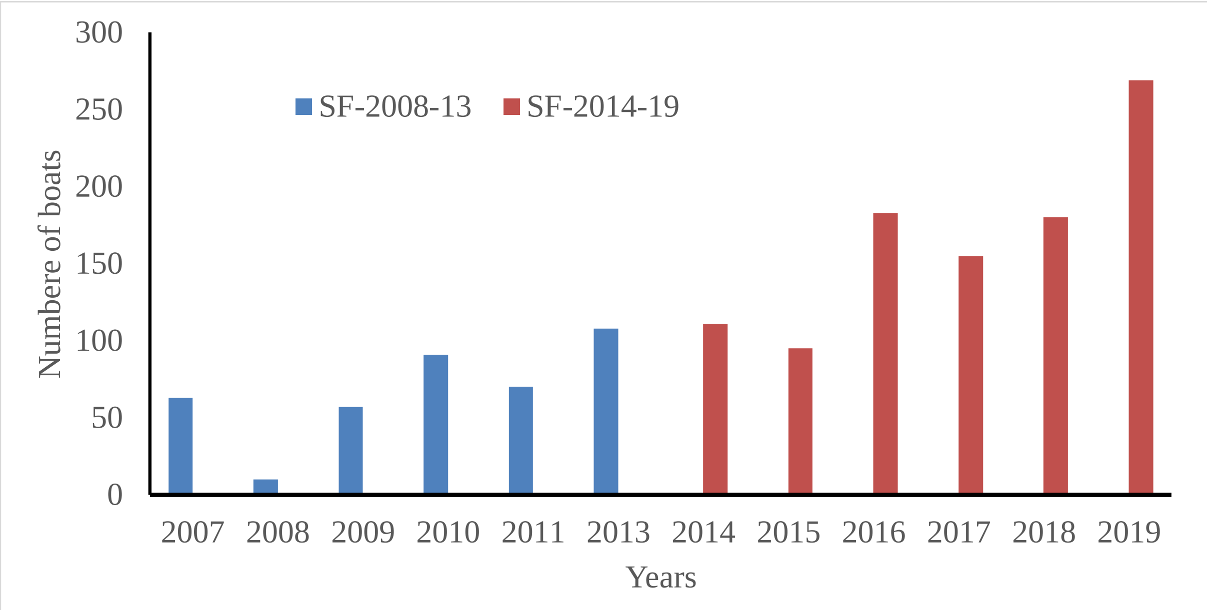

Figure 4.8-1: Number Ssese flat One end fishing boats on Upper Victoria Nile, Bujagali area

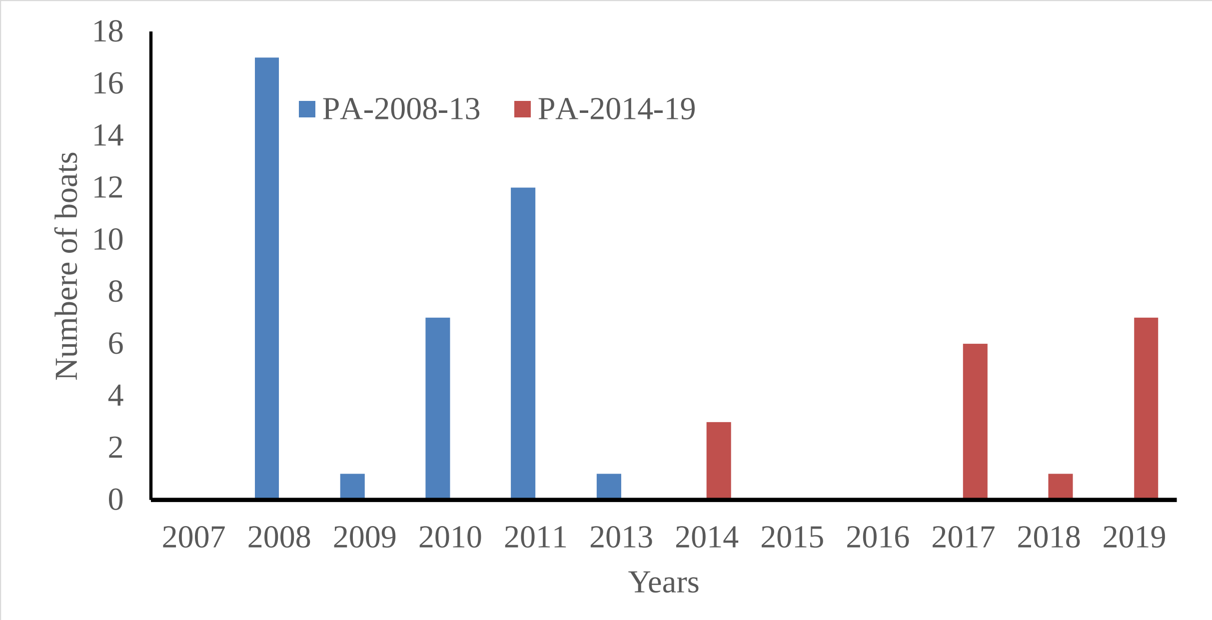

Figure 4.8-2: Number of Parachute (PA)fishing boats on Upper Victoria Nile

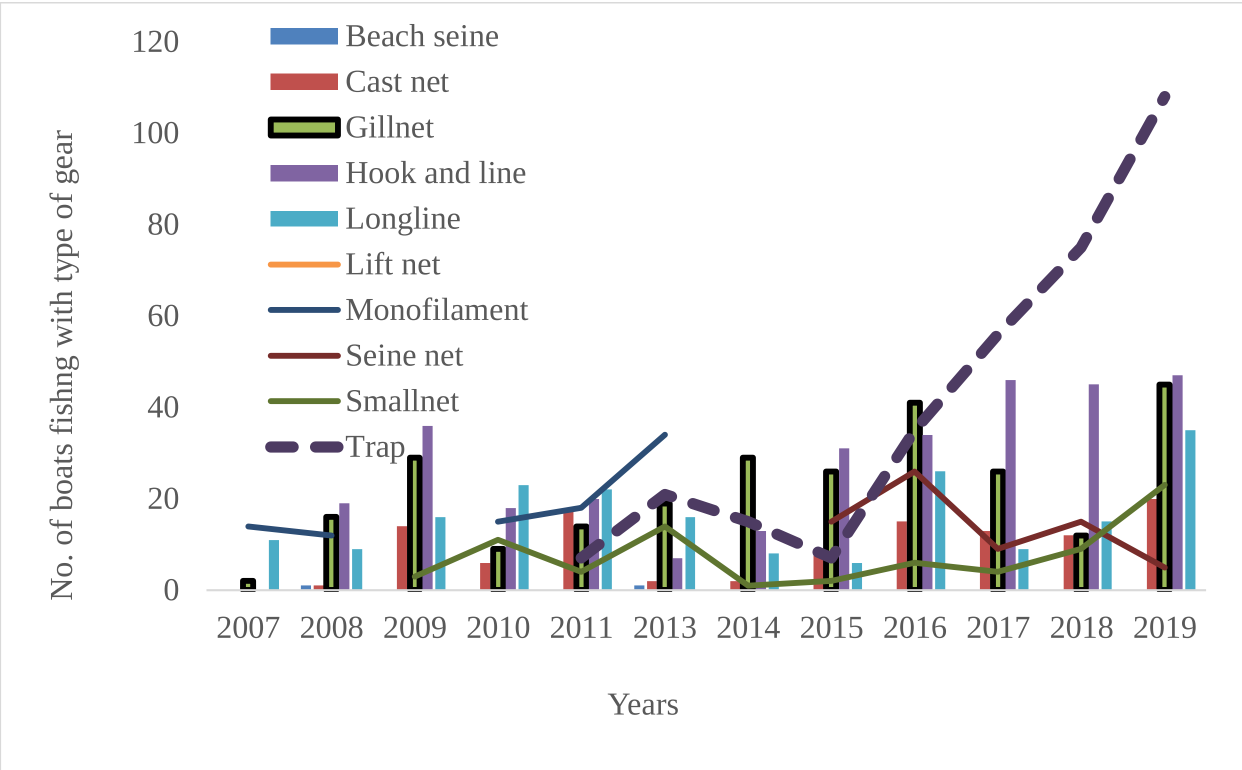

Figure 4.8-3: Boat gear category on Upper Victoria Nile

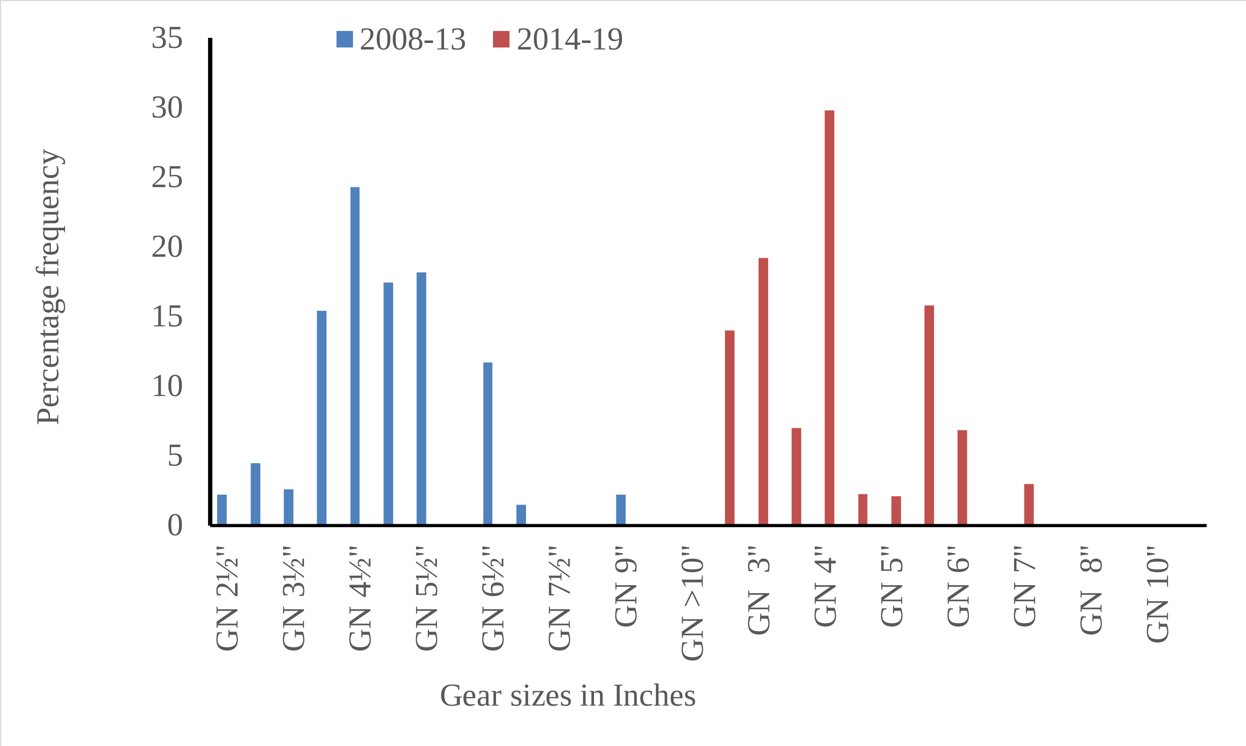

Figure 4.8-4: Gillnets sampled from Upper Victoria Nile

Six hundred and seventy one (671) gillnets were sampled from 2014 to 2019. Findings from the study showed that 72.3% were all below the recommended sizes of 5 inches (Figure 4.8-4). On the contrary, five hundred and thirty nine (539) obtained 48.98% below 5 inches from 2008-2013. Sixteen thousand four hundred and twenty five (16,425) fishing gears were obtained in the sampled period. Of which50.71% were long lines and 25.2% were basket traps. In 2008 to 2013 ten thousand and forty four (10,044) fishing gears were sampled. Of which, 77.75% were beach seines and 12.73% were basket traps (Figure 4.8-5).

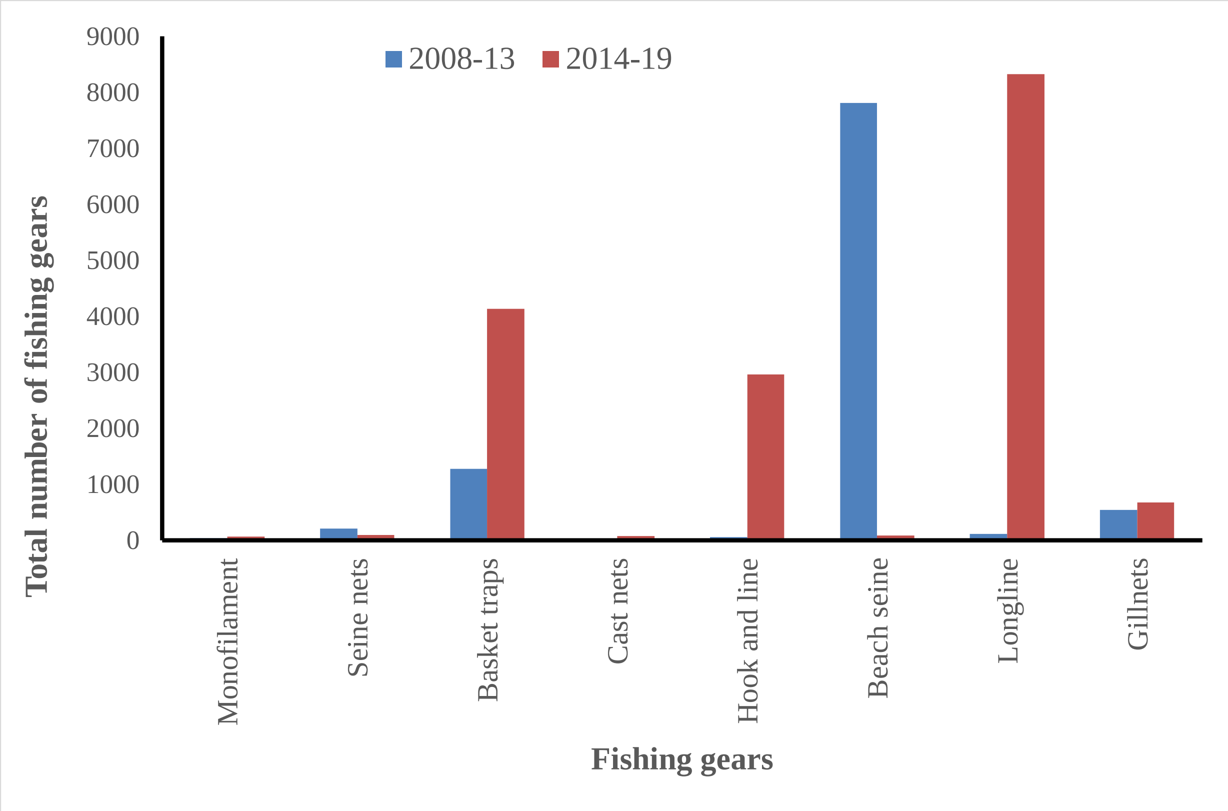

Figure 4.8-5: Fishing gears sampled from Upper Victoria Nile

4.9.2 Total catch rates and Annual Catch Landings, Upper Victoria Nile

Fifteen (15) fish species were obtained during CAS from the UVN, including *Bagrus docmac, Labeo barbus altinialis,Clarias gariepinus, Coptodon zilli*, Haplochromines spp, *Labeo victorianus, Lates niloticus, Mormyrus Kannume, Oreochromis leucostictus, Oreochromis niloticus, Oreochromis variabilis, Protopterus aethiopicus, Rastrineobola argentea, Synodontis afrofisheri* and *Synodontis victoriae.* The total catch rates obtained from 2014-2019 showed higher catches compared to 2008-2013 of whichthe catch per unit of effort (CPUE) recorded 6.00kg/boat /day (Figure 4.8-6)

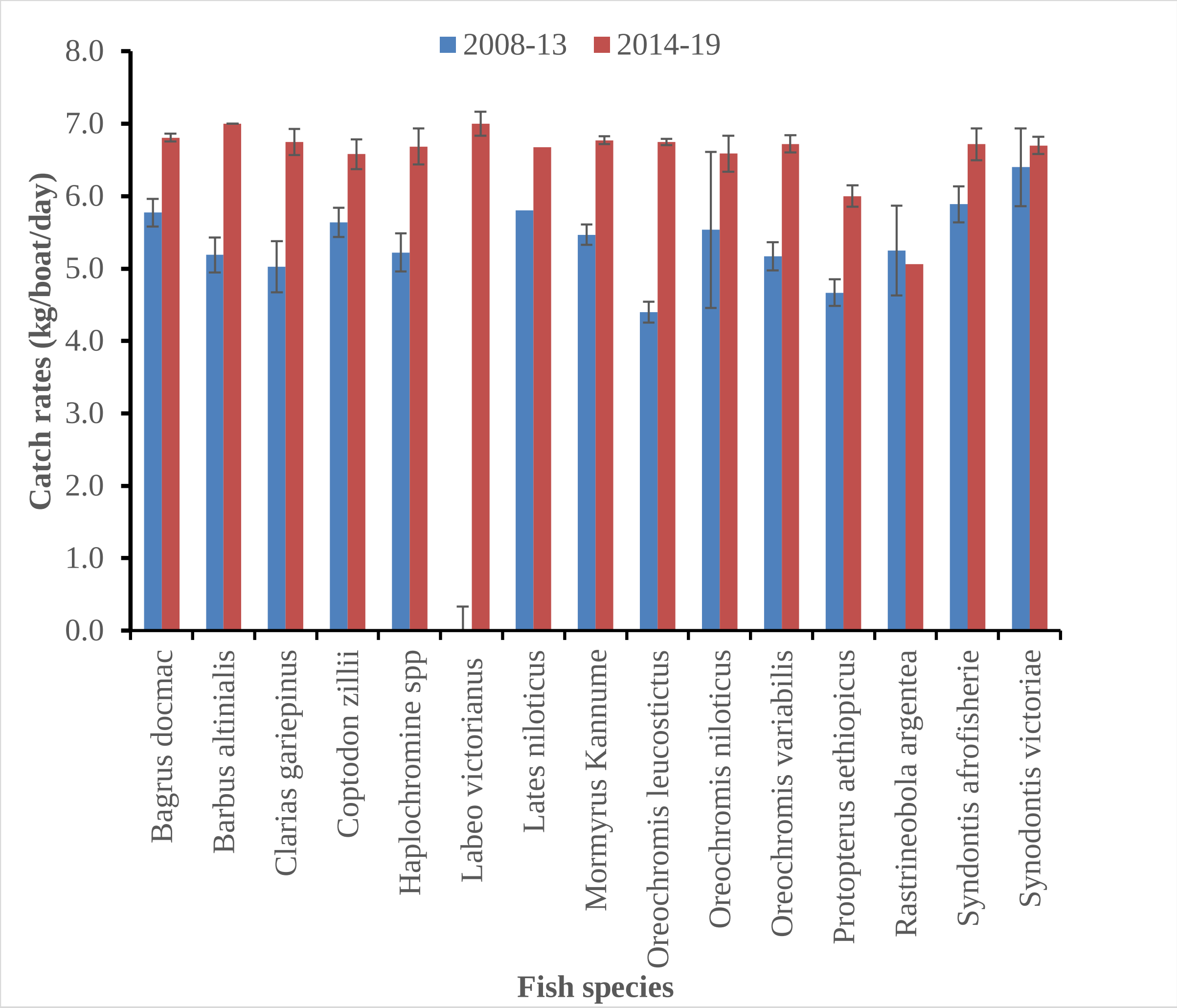

Figure 4.8-6: Catch rates (kg/boat/day) CAS sampled from Upper Victoria Nile

Annual fish catches recorded variations in catch estimates with the lowest observed in 2017 (156.88±5.44) and the highest in 2019 (1,072.41±164.46) (Figure 4.8-6). Observations were made in the previous catches from 2008 to 2013 (Figure 4.8-8).

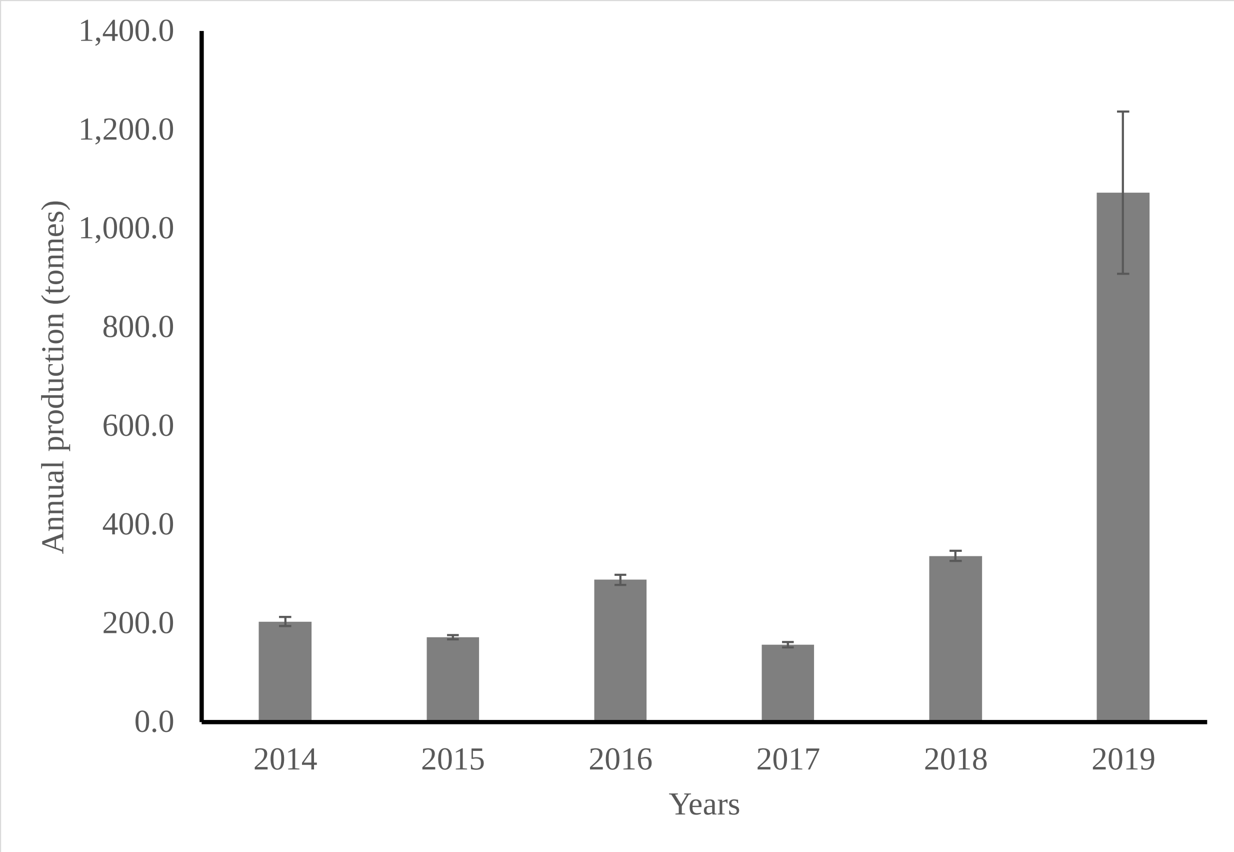

Figure 4.8-7: Annual catches from the Catch assessment data obtained from the UVN

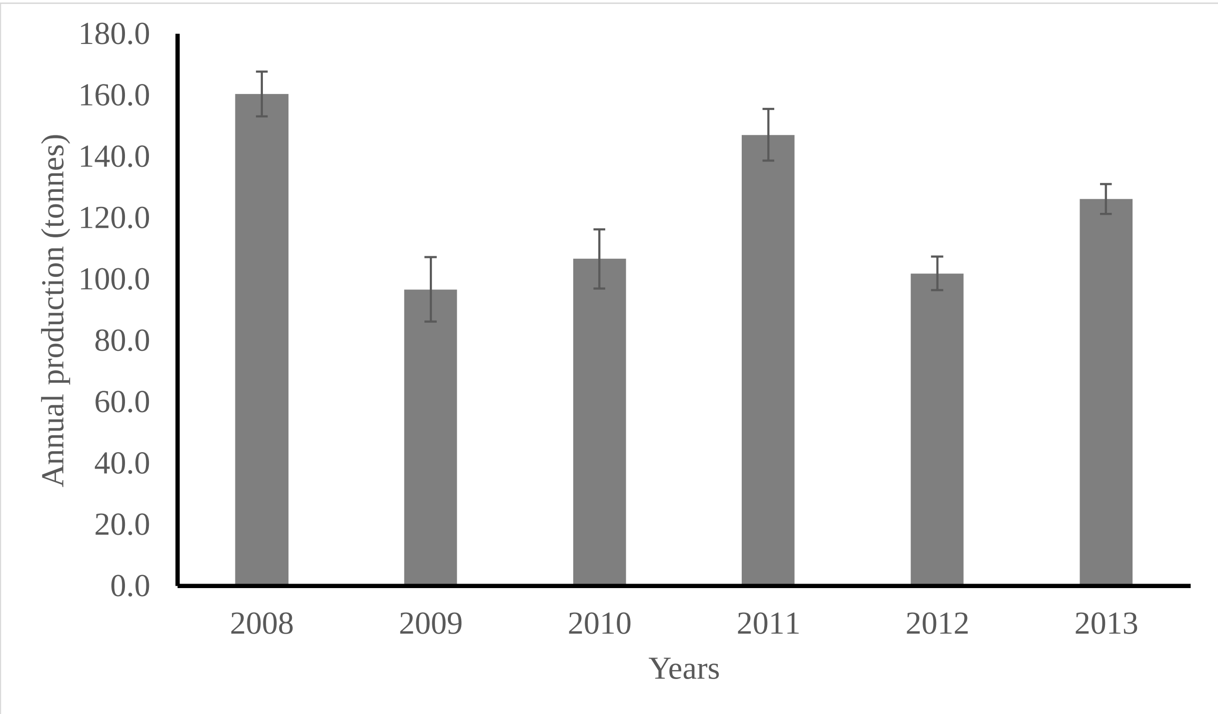

Figure 4.8-8: Annual catches from the Catch assessment data obtained from the UVN

4.9.3 Percentage Composition of Fish Species of the Upper Nile

In the study, *L. niloticus* (28.3%) was highly exploited followed by *R.argentae* (27.74%) and *M.kannume* (16.7%).The least was *Labeo victorianus* (0.03%) and *O.leucostictus* (0.01%). Yet for 2008-2013 the highly exploited fish species was *Labeo barbus altinialis* 19.0% followed by *M. kannume* 18.55% then *L. niloticus* 17.15% the lowest species was *S.victoriae* at 0.03% (Table 4.7-1).

Table 4.7-1: Fish species with their catches and percentage composition on the upper Nile for period sampled

Fish Species	2014-2019 (Catch-tonnes)	Percentage contribution	2008-13 (Catch-tonnes)	Percentage contribution
Bagrus docmac	143.82	6.48	45.58	6.39
***Labeo barbus** altinialis*	43.65	1.97	135.51	19.01
Clarias gariepinus	107.29	4.83	33.06	4.64
Coptodon zilli	33.89	1.53	28.65	4.02
Haplochromines spp	143.94	6.48	2.56	0.36
Labeo victorianus	0.68	0.03	-	-
Lates niloticus	628.06	28.29	122.26	17.15
Mormyrus Kannume	371.74	16.74	132.24	18.55
Oreochromis leucostictus	0.22	0.01	0.40	0.06
Oreochromis niloticus	64.86	2.92	54.59	7.66
Oreochromis variabilis	28.99	1.31	51.71	7.26
Protopterus aethiopicus	3.70	0.17	7.40	1.04
Rastrineobola argentea	615.85	27.74	98.07	13.76
Synodontis afrofisheri	29.19	1.31	0.45	0.06
Synodontis victoriae	4.46	0.20	0.23	0.03

The gear that landed the highest catch was the seine net (34.9%) that harvested*R. argentae* followed by the basket traps (25.9%) that targeted *M. kannume* and the gillnets (20.9%) that targeted*L. niloticus, Tilapia, Labeo barbus altinialis* and Bagrus species (Figure 4.8-9).

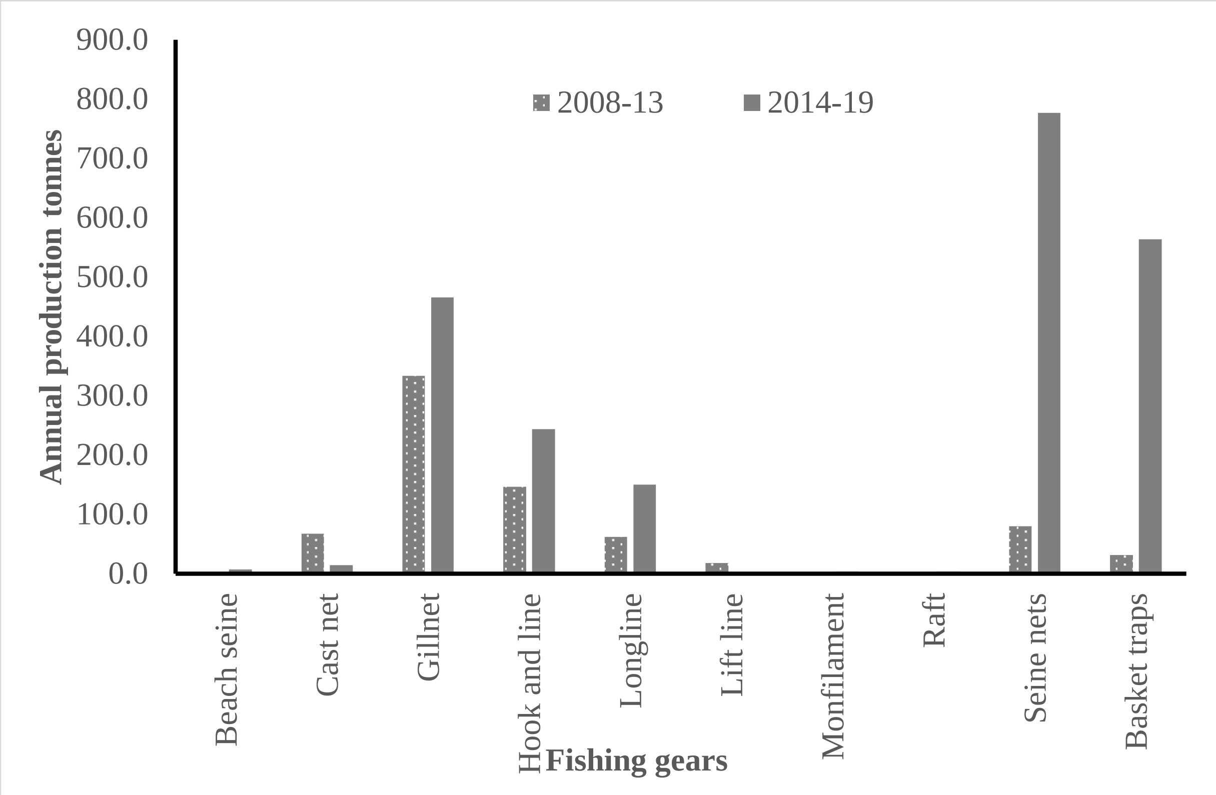

Figure 4.8-9: Annual catches by fishing gear types from the Catch assessment data.

4.9.6Catches variations of Individual Fish Species in the UVN

4.9.6.1 Catch variations of the Nile perch (*Lates niloticus*) in the UVN

The total catches of Nile perch sampled from the UVN ranged from 17.85±1.01 to 385±34.73 tonnes from 2014- 2019 as compared to the 2008 -2013 studythat ranged from 12.93±2.5 to 29.60±0.99 metric tonnes.In 2019, Nile perch recorded the highest catchesas observed in the study.The Nile perch production for the sampled period 2014-2019 was 628.6± 43.73 tonnes compared to 122.26±9.78 tonnes from 2008 to 2013 (Figure 4.8-10).

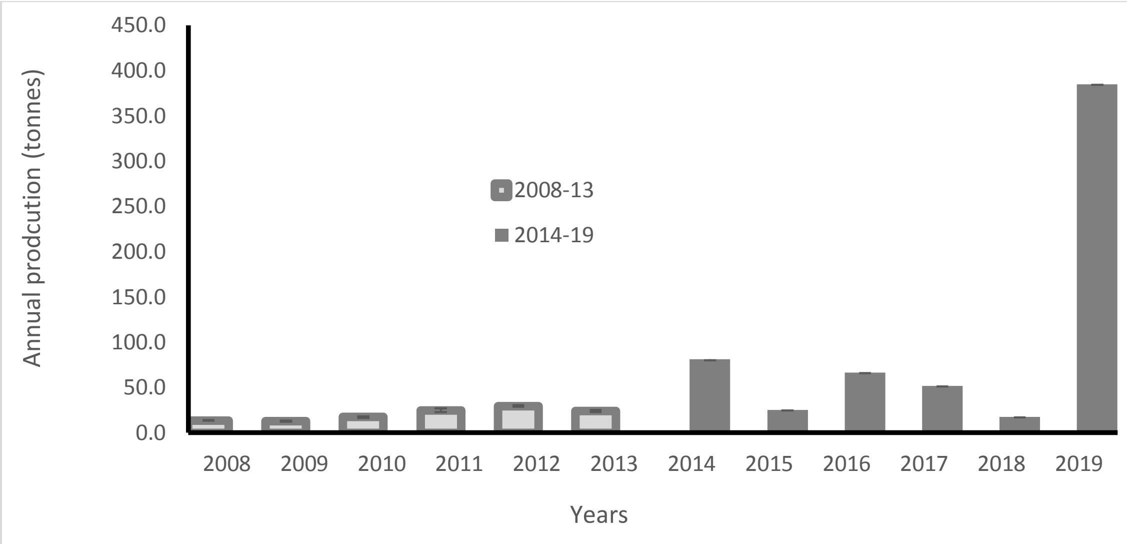

Figure 4.8-10: Annual catches of *Lates niloticus* during 2014-2019 compared with 2008 – 2013 studies in the Upper Victoria Nile.

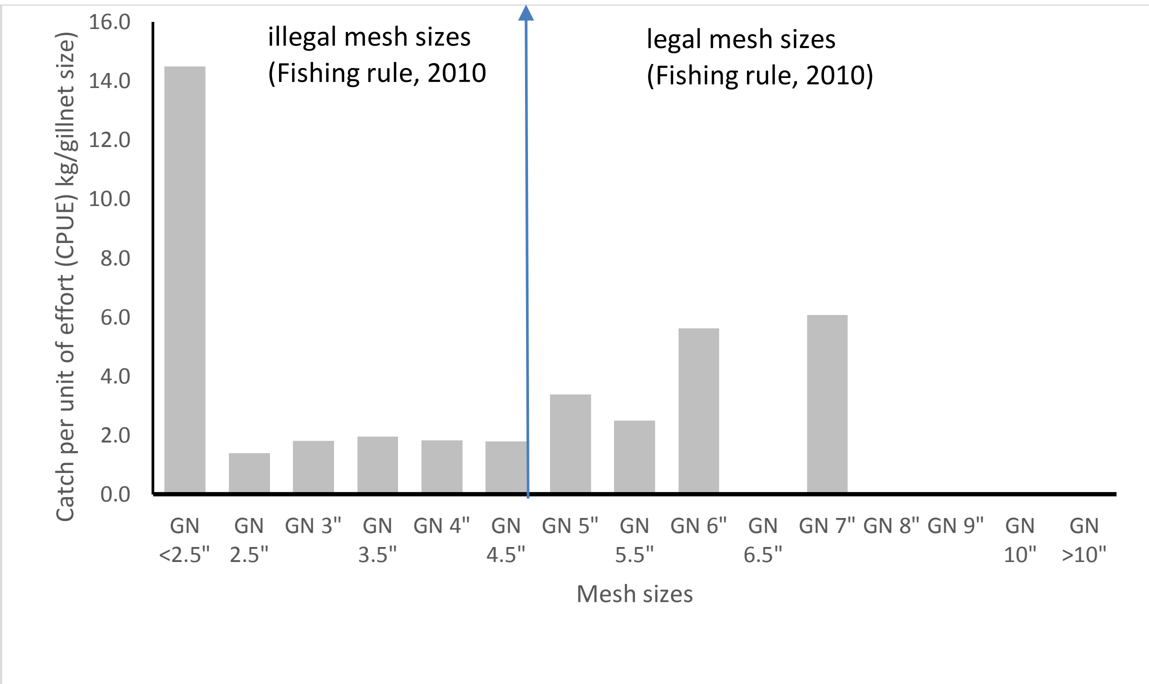

Figure 4.8-11: Catch per unit of effort (kg/net size) of *L. niloticus*(2014-2019).

The gillnet gear, one of the dominants for Nile perch exploitation, showed 57% of the catches from sizes below 5 inches in 2014-2019 compared to 80% in 2008-2013 (Figures 4.8-10&4.8-11).

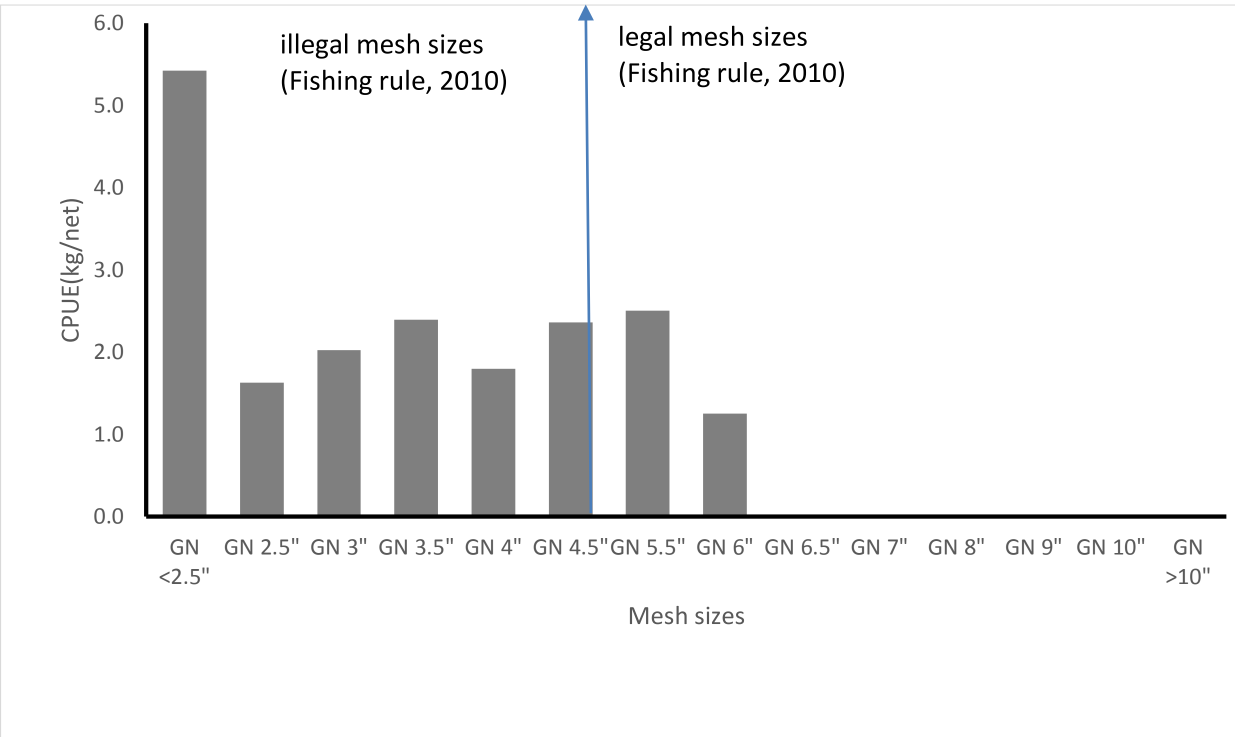

Figure 4.8-12: Catch per unit of effort (kg/net size) *L. niloticus*(2008-2013)

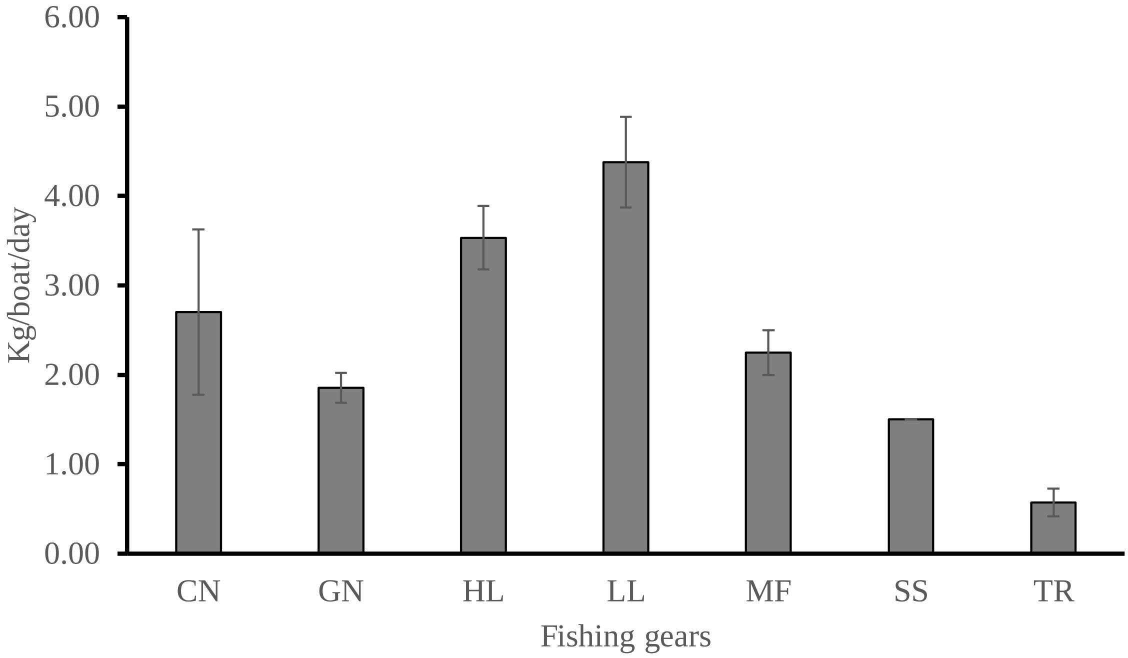

Figure 4.8-13: Catch per unit of effort (kg/boat/day) to the fishing gears

The fishing gear sizes showed that 61.4% of the Nile perch were caught by illegal gear such as cast nets, traps and monofilaments as compared to others (Figure 4.8-13) according to the Fishing rule (2010). The gillnets also showed that smaller mesh sizes caught most of the fishes than legally recommended sizes of 5 inches (Figure 4.8-11 and 4.8-12).

4.9.6.2 Catch variations of the *Oreochromis niloticus* Linnaeus, 1758 (Nile Tilapia)

The total catches of Nile tilapia sampled from the UVN varied from 0.65±0.00 to 30.93±9.16 tonnes from 2014- 2019 whereasthe 2008 -2013 study found that total catch varied from 2.26±0.55 to 14.61±0.07 metric tonnes (Figure 4.8-14). Similarly, Nile tilapia catches showed high increase in the year 2019.The production of the Nile tilapia from 2014-2019 was 64.86± 11.19 tonnes compared to 54.59±4.59 tonnes between 2008 to2013.

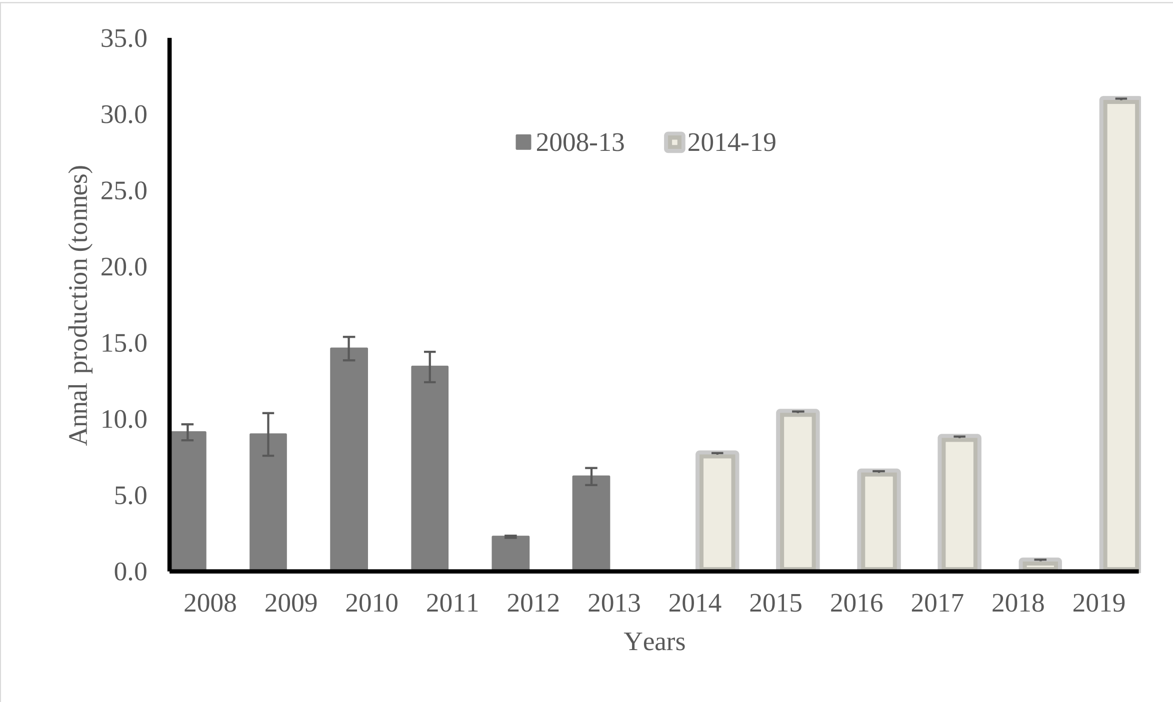

Figure 4.8-14: Annual catches of *Oreochromis niloticus* from UVN

Results from the Nile tilapia exploitation using the gillnet gear showed58.61% of the catches from sizes below 5 inches in 2014-2019 compared to 80% in 2008-2013 (Figures 4.8-14 & 4.8-15).

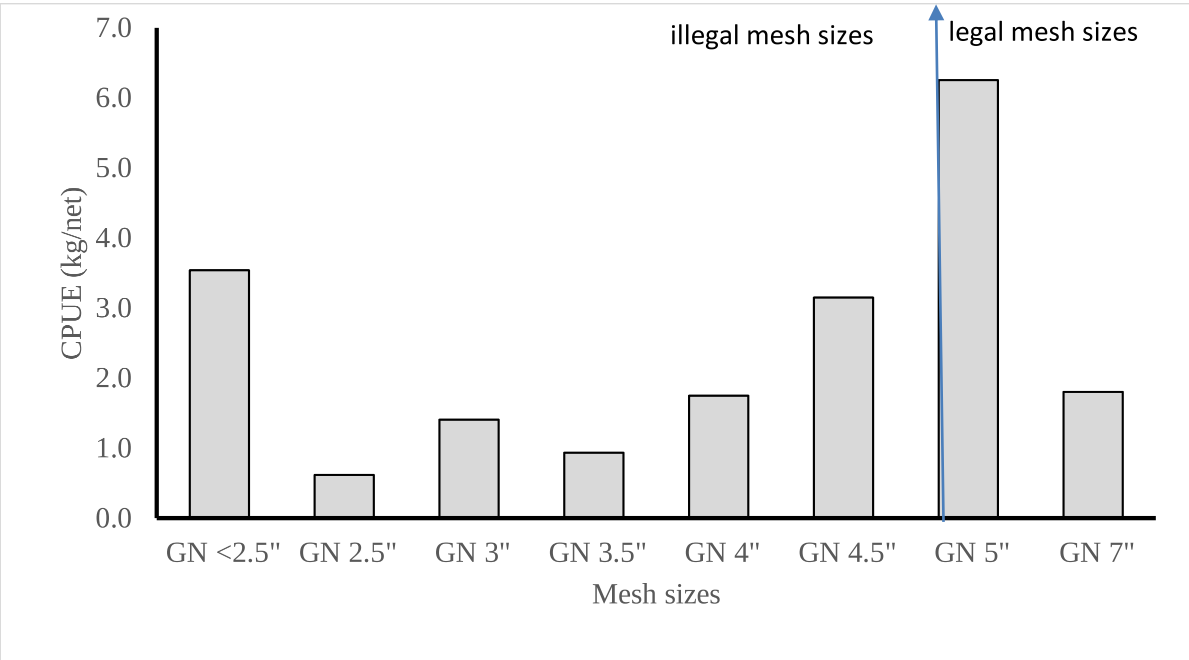

Figure 4.8-15: Catch per unit of effort (kg/net size) for*O. niloticus*(2014-2019) from UVN

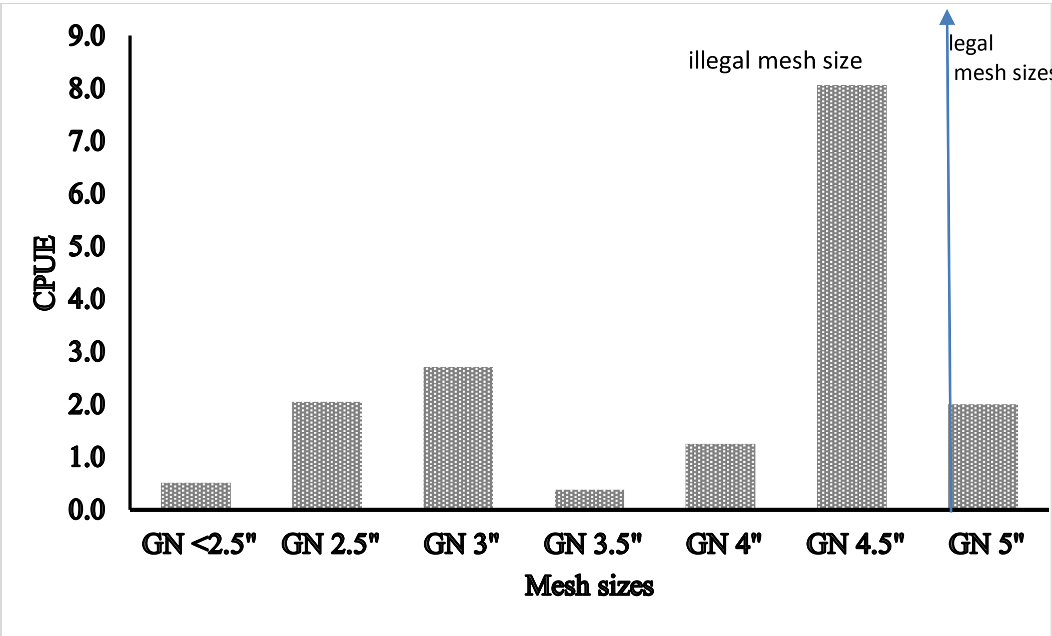

Figure 4.8-16: Catch per unit of effort (kg/net size) for *O. niloticus* (2008-2013)from UVN

4.9.6.3 Catch variations of the Victoria tilapia (*Oreochromis variabilis)*

Results from the study sites showed that the total catches of Victoria tilapia varied from 0.81±0.03 to 14.80±0.97 tonnes from 2014-2019 compared to the 2008-2013 studywere 4.04±0.25 to 13.08±0.61 metric tonnes were reported (Figure 4.8-17). Victoria tilapia catches showed a high increase in the year 2019 like other fish species attributed to changes in the weather patterns.

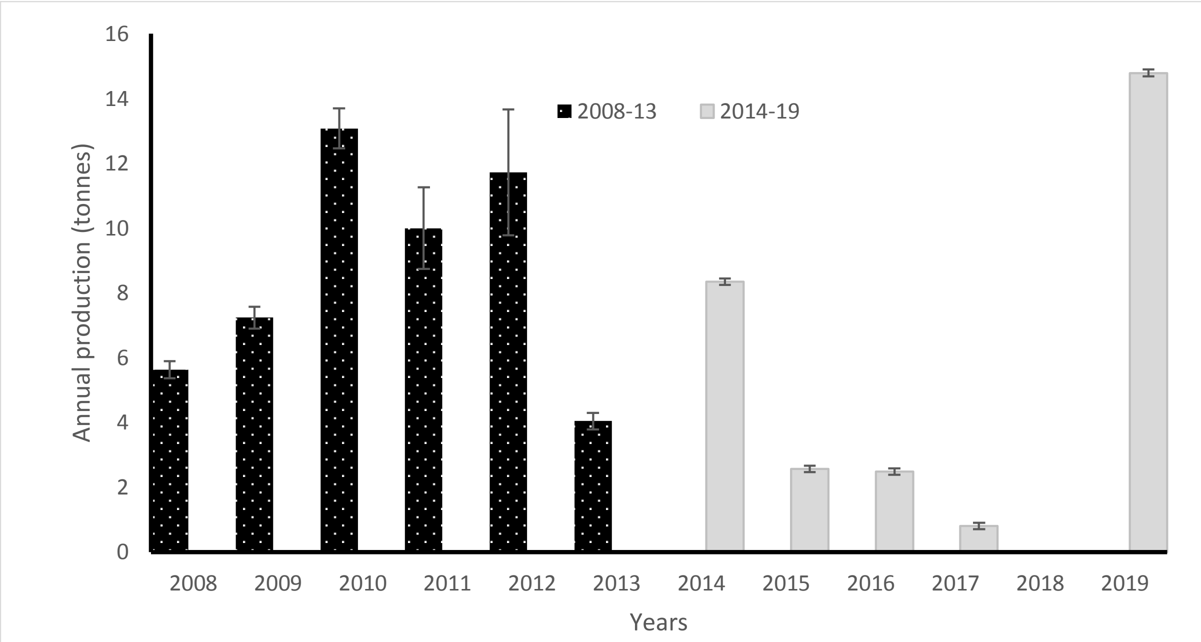

Figure 4.8-17: Annual production variations for *Oreochromis variabilis* from the Catch assessment Survey from UVN

4.10 Spatial and Temporal Distribution And abundance of the Bait Fishery Of *Mormyrus KANNUME*, ELEPHANT SNOUT FISH IN THE UVN

4.10.1. Length-Weight Relationship

The length ranged from 10.7 to 67 cm (Total length-FL) andthe average weight was 0.278±0.114kg/gear/day.The total length-weight relationship was calculated as: $W= 0.009857L^{3.0}$ (R^2= 0.9895) n=278. implying that the fish had an isometric growth (Table 4.8-2).

ANOVA test showed a significant difference of F=25464.58, df =270, P<0.05 These findings were compared with the 2008- 2013 study that found that $W=0.013162L^{3.0}$ (R^2= 0.9318), n=477 in range of 10.8-69 cmFL with average weight of 0.235±0.017 kg/gear/day. ANOVA testshowed a significant difference of F=6490.67, df =476, P<0.05.

Table 4.8-2 Length-Weight Relationship

Year	No.	a	b	R2
2008-2013	278	0.00985	3.0	0.9895
2014-2019	477	0.013162	3.0	0.9318

4.10.2 Growth Parameters of *M. kannume*

Population parameters of the *M. kannume* were estimated using the fish stock assessment tool of FISAT II underthe ELEFAN method. The von Bertalanffy growth parameters of *M. kannume*were estimated as L_∞ =69.30 (FL cm) and growth coefficient K=0.150 per year (Figure 4.9-18). The t_o value (time in years at the time of birth) was calculated by Pauly's equation denoted as: $l_t=L_\infty= (1-\exp (-k(t-t_o)))$

The value of the time, t_o is the hypothetical age t_o= -1.14113, when the length of the virtual age is considered zero. The $t_o$value was estimated using Pauly's equation; Log_{10} (-t_o) =0.3922-0.275$Log_{10}L_\infty$-1.028Log_{10}K per year.

The $t_{max}$was estimated as at t_{max}=18.9 years as the maximum age for the species recorded for the whole period of sampling. The growth performance indices based on asymptotic length (L_∞) and asymptotic weight (W_∞) were Ø= 2.858per year and Ø=1.579 per year. Rn=0.129 were carried out for *M.kannume* from the riverine of the UVN waters (Figure 4.9-19). Thestudy findings were compared with those of 2008-2013 that found that, L_∞=73.50, (FL cm), K=0.20 yr^{-1}, to=-1.0544 years, t_{max}= 13.9 years, Rn=0.109, (Figures 4.9-18 & 4.9-19).

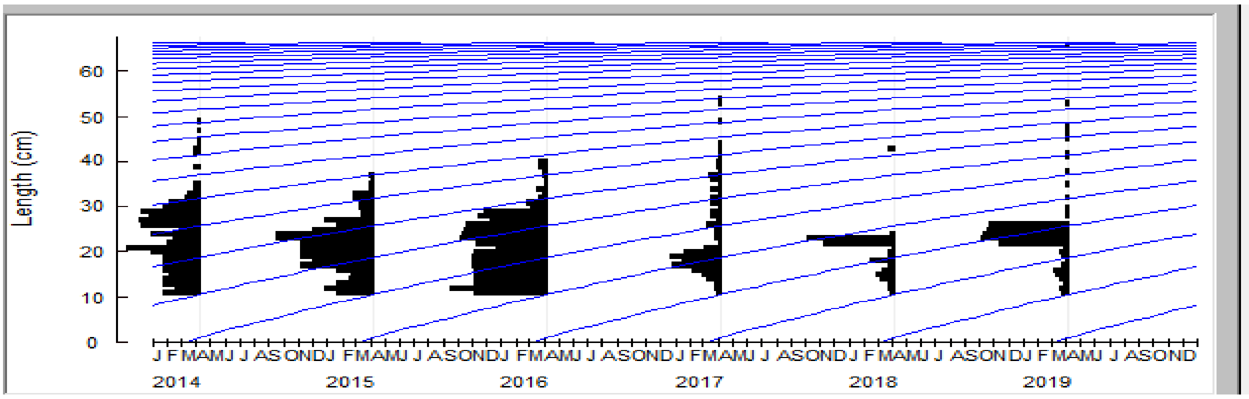

Figure 4.8-18: The VBGF and length-frequency plot (2014-2019) from UVN

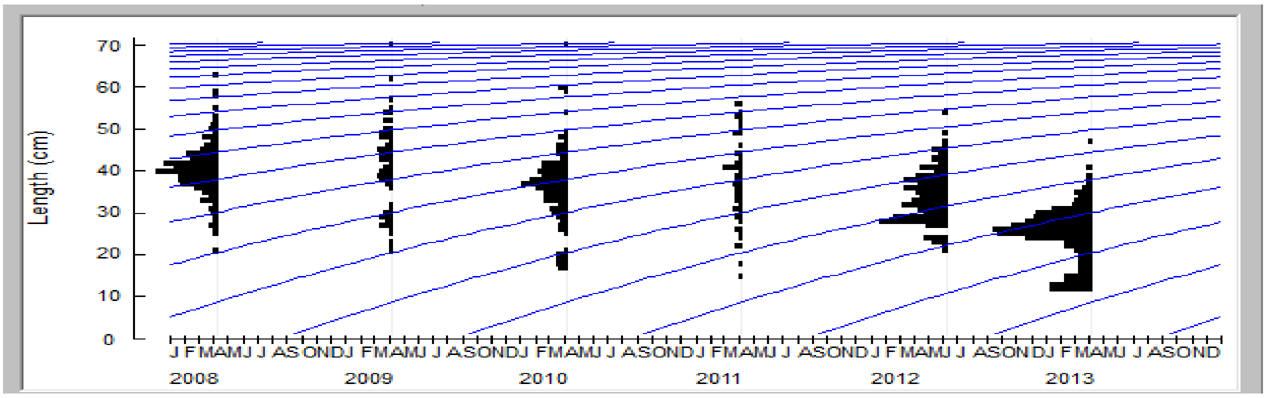

Figure 4.8-19: The VBGF and length-frequency plot (2008-2013) from UVN

4.10.3 Mortality Estimates of *M. kannume*

The total mortality rate (Z) of *M. kannume*was estimated using a catch curve analysis represented in Figure (4.9-20). The total mortality estimated Z=1.05 yr^{-1} wasestimated at 95% confidence interval (CL= 0.93-1.18).

The value of natural mortality (M) estimated from (Pauly's formulae) was M=0.40 yr^{-1} using the riverine surface temperature of (RST) 26°C. Thus, the fishing mortality was calculated as: F=Z-M=0.66 $yr^{-1}$and exploitation ratio (E) was calculated from F/Z=0.62. Exploitation rate at 10% was 0.266 and at 50% was 0.227, E_{max}=0.351, B/Y of 0.50 and Y/R of 0.01. The results were compared with 2008-2013 study that foundZ=1.01 per year, M=0.47 per year, F=0.54 per year and E=0.54. The exploitation rate at 10% was 0.257 while at 50%, the rate was 0.232 and E_{max}=0.358 and B/Y of 0.50, Y/R of 0.01 (4.9-20, 21, 24, 25, 26, 27, 28, 29).

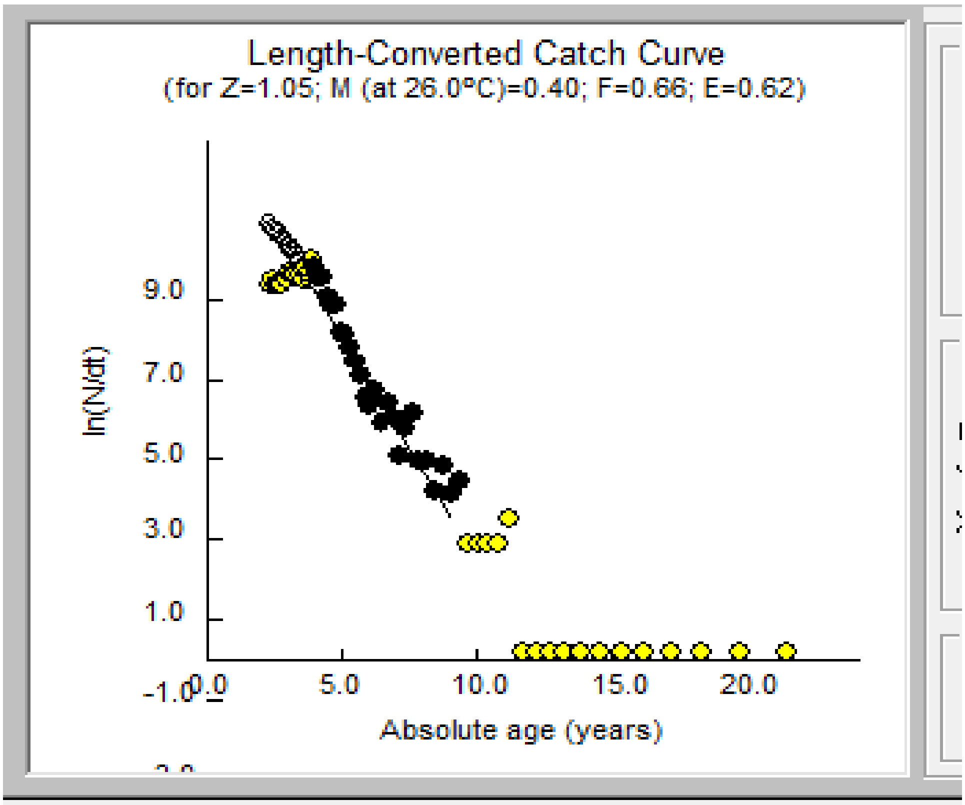

Figure 4.8-20: The Length converted catch curve (2014-2019) from UVN

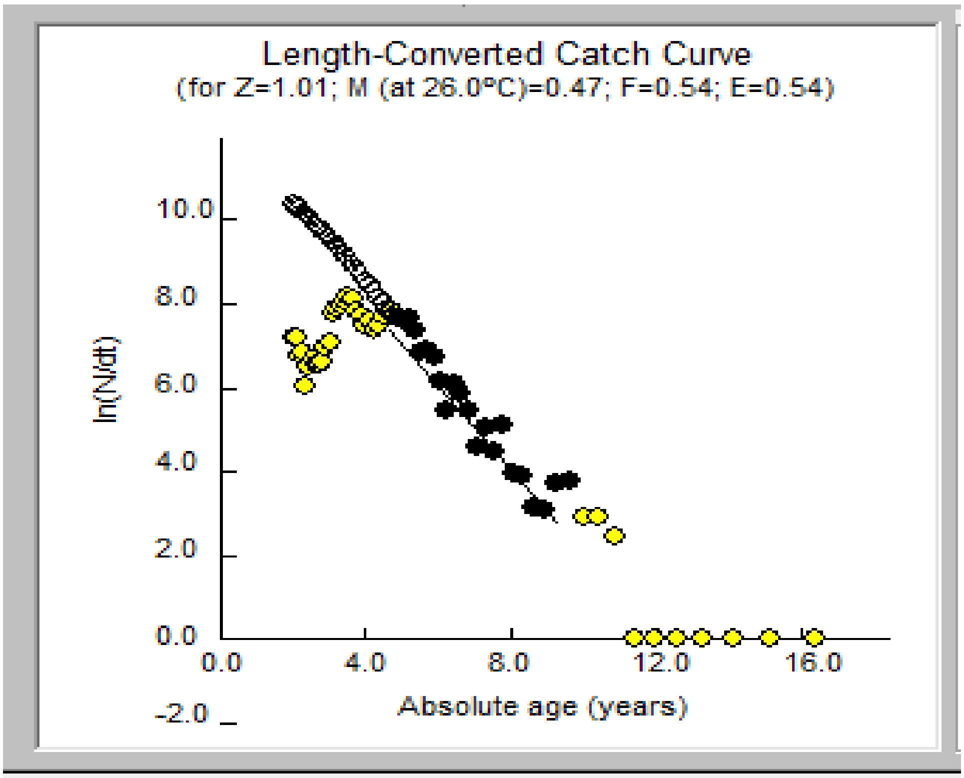

Figure 4.8-21: The Length converted catch curve (2008-2013) from UVN

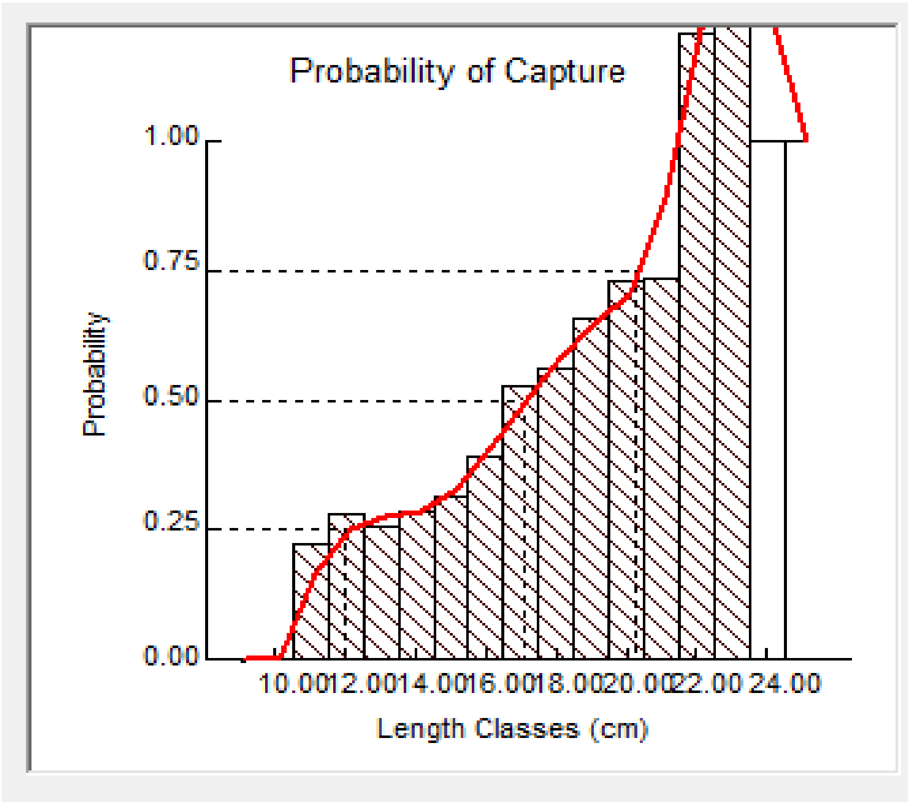

Figure 4.8-22: The Probability of capture (2014-2019) from UVN

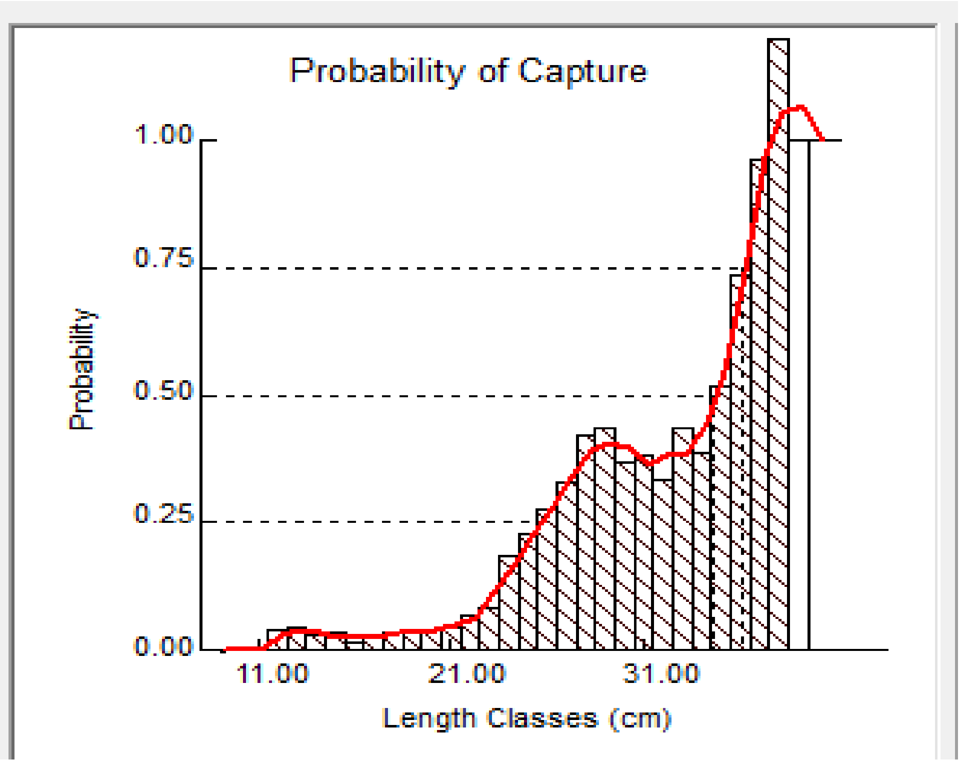

Figure 4.8-23: The Probability of capture (2008-2013) from UVN

The study showed two peaks recruitment period, a minor in May and a major in October, accounting for 11.13% and 19.07%, respectively. The 2008-2013 study showed a minor in March and a major in August, accounting for 6.28% and 19.29%, respectively (Figures 4.9-22 &4.9-23). The probability of capture indicated at least 25% of fish of 11.97 cm FL, 50% of the fish of 17.01 cm FL, and 75% of all fish of 20.25 cm FL retained on encounter with the gear (Figure 4.9-23).

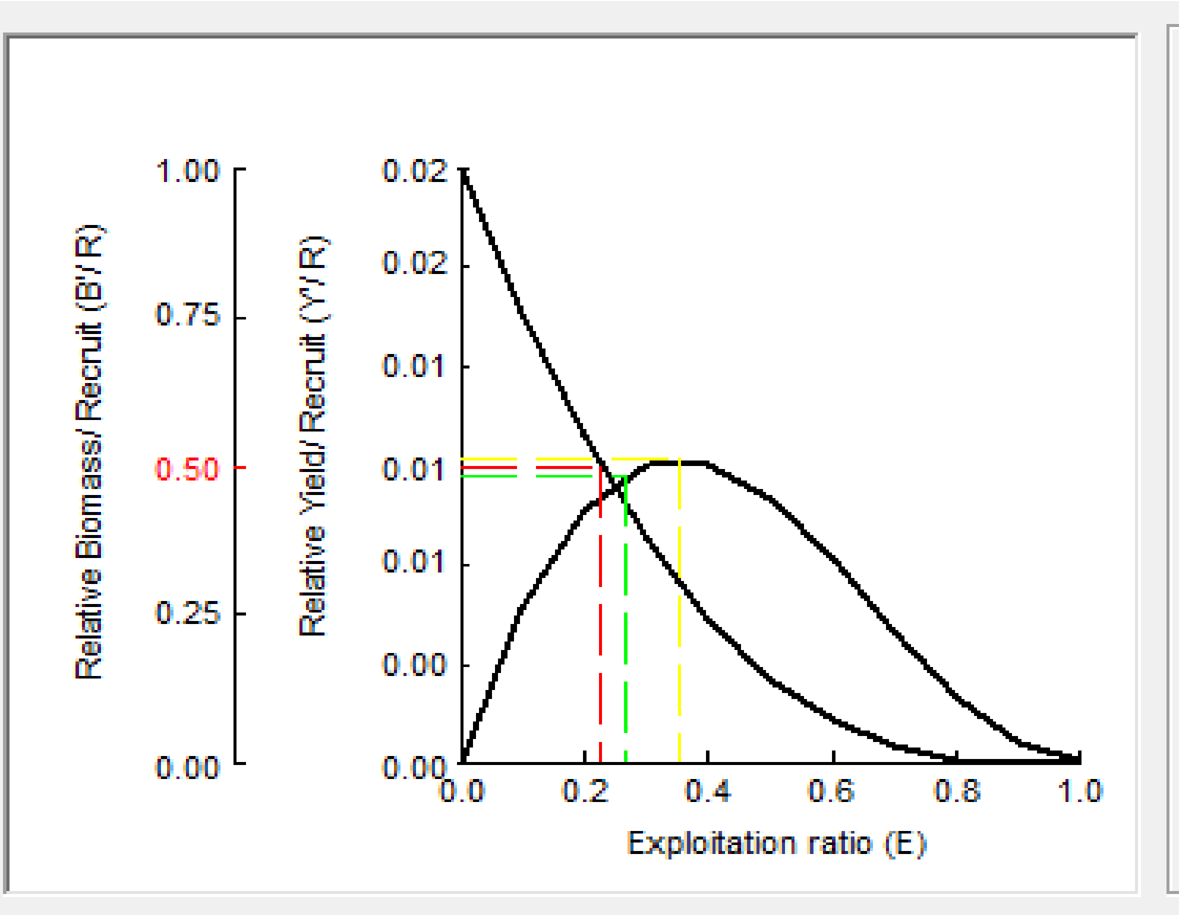

Figure 4.8-24: The Relative Y/R and B/R (Knife-edge selection) (2014-2019) from UVN

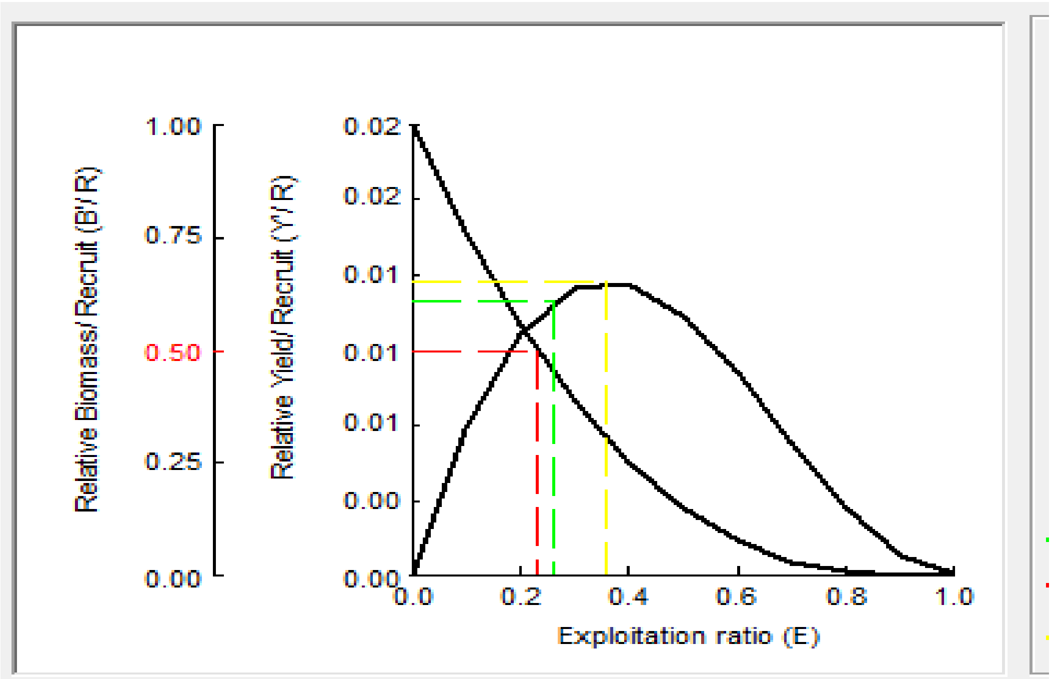

Figure 4.8-25: The Relative Y/R and B/R (Knife-edge selection) (2008-2013) from UVN

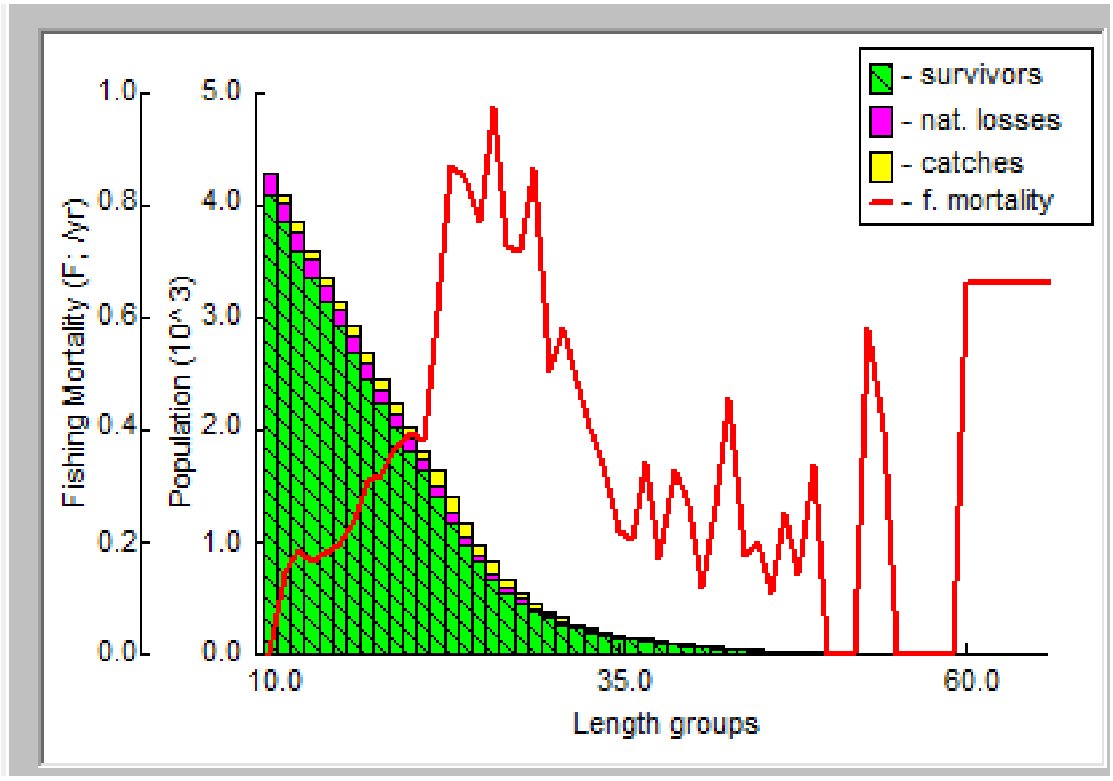

Figure 4.8-26: The Length- structured Virtual Population Analysis (VPA) (2014-2019) form UVN

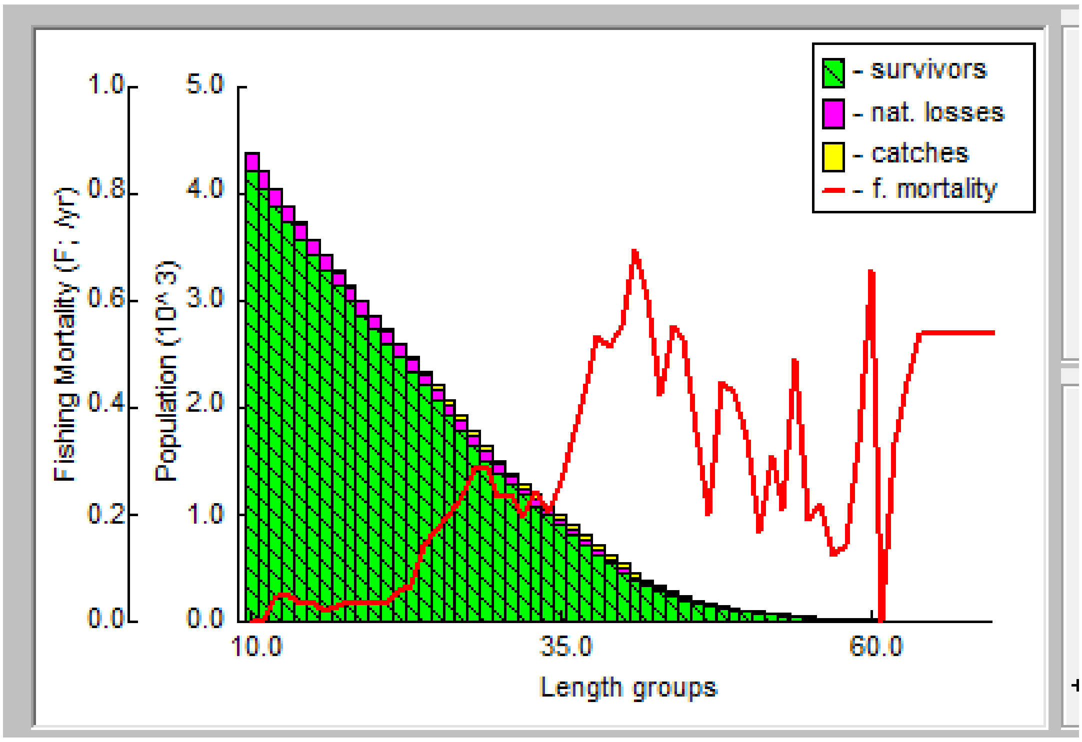

Figure 4.8-27: The Length- structured Virtual Population Analysis (VPA) (2008-2013) from UVN

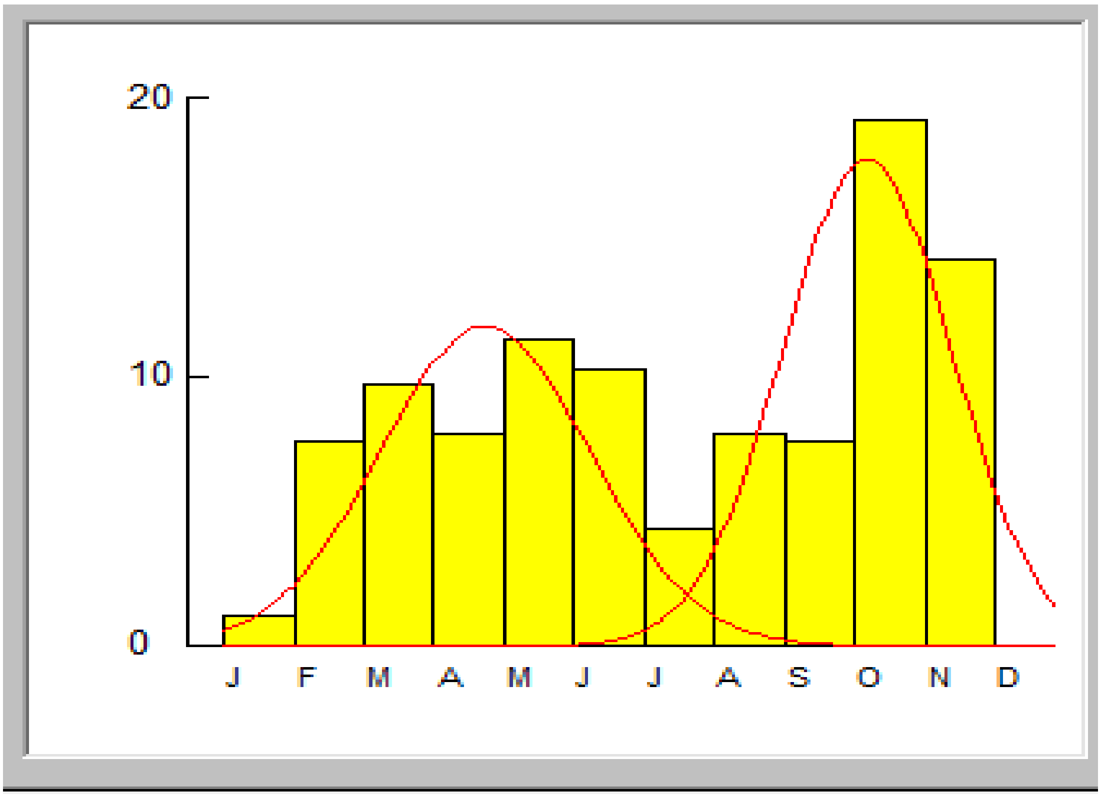

Figure 4.8-28: The Recruitment pattern (2014-2019) from UVN

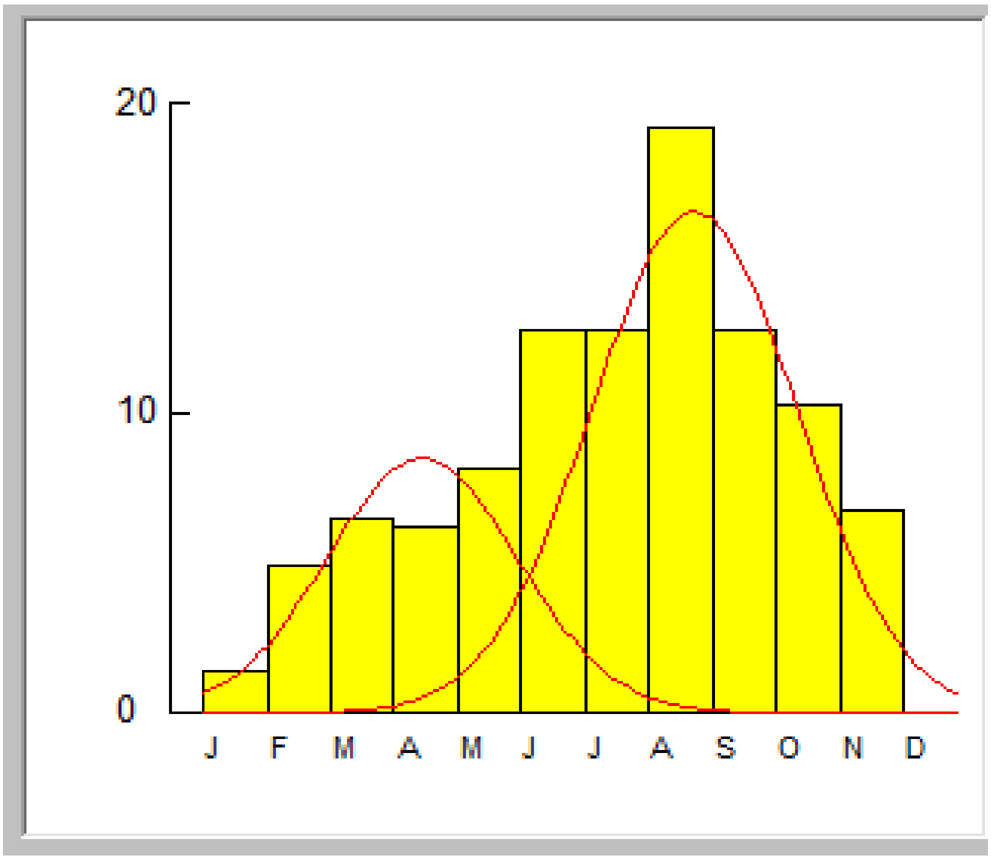

Figure 4.8-29: The Recruitment pattern (2008-2013) from UVN

4.10.4 Sex Ratios for *Mormyrus kannume*

One hundred andtwenty-one (121) *M. kannume* samples from UVN were collected from experimental gillnets. Females were 70, males were 51, constituting a ratio of 1.4:1. This ratio was significantly deviating from the hypothetical 1:1 female to males' ratio. Chi-square test indicated males (X^2=76.783, df=6, P<0.05) and females (X^2, F=173.425, df=6, P<0.05).

4.10.5 The harvestable levels Relative Catches and Value

There were temporal and spatial variations in the catch rates for the Elephant snout fish recorded from the UVN. Results showed the highest of 16.88±5.41kg/boat/day in ST11 in 2019 and the lowest at ST120.89±0.17 kg/boat/day in 2018. Temporal distribution of the catches indicated a decreasing trend at ST12 and an increasing trend at ST11 (Table 4.9-1).

On the contrary, the temporal trends indicated a decreasing trend from 2014 to 2019 implyingan intensive exploitation of UVN fishery over time and space as recorded in the size structure. The results showed variations in catches harvested using basket traps from 1.00±0.10 to 7.30±0.00 kg/boat/day duringthe sampled period. This catch was worthUS$1.72±0.00 to 1.83±0.01, theaverage price between 2014 and2019. In comparison to the previous study, the 2012 catch rates of 1.94±0.49kg/boat per day were recorded when basket traps with catch rates of 1.6±1.40kg/boat/day came into use. Between 2012 and 2016, there was a three-fold (c.443percentage) increase in the fish catch harvested by basket traps (Table 4.9-2). The average price of *M. kannume* rose from 0.41±0.00 US$ in 2012 to 2.43±0.21 US$ per kg in 2016 for the fishes harvested by basket traps compared to those harvested using other gears with 0.34±0.03 to 0.77±0.10 US$ per kg/boat/day in the respective years in the Upper Victoria Nile (Table 4.8-3). The harvest of bait fishery was high in ST11 as compared to other sites. Analysis of variance (ANOVA) test for differences in means per boat per day of*M. kannume* indicated a significant difference of (F=3.855501: df=332; P<0.05).

The annual production showed 40 to 300 tonnes in 2014 to 2019 compared to 5 to 28 tonnes from2008 to 2018 with corresponding increase in value from 1.2 (000) US$ to 130 (000) US$ in the same sampling periods. (Figure 4.9-1).

4.10.6 Length at first Maturity of*M.kannume*

The length at first maturity of *M.kannume* sampled in 2014-2019 obtained L_{50} for male and females as 24.5 and 17.5 cm FL respectively. On the contrary, the length at first maturity from 2008 to 2013 recorded 25.5 and 17.5 cm FL for males and females respectively (Figures, 4.9-2 and 4.9-3).

4.10.7 Size structure for *M.kannume*

The size structure and population characteristics indicated the fish harvested were below the L_{50} maturity as observed in the length-frequency information from experimental data whereL_{50} for males and females were 24.5 and 17.5 cm fork length, respectively (Figure 4.9-2). The fish harvested during sampling ranged from 9.0 – 69.0 cm fork length in the early years, 95% of the fish above L_{50}; and 73% below the size at first maturity (Figure 4.9-2). The fishes exploited overtime recorded a decreasing trend in size structure but a high abundance as indicated in Figure 4.9-4.

4.10.8 Food and Feeding Interactions

Fourteen (14) dominant food types were identified. Some of the types in the 2014-2019 studyincluded; Rastrineobola argentae, Fish remains, Povilla, Ephemeroptera, Povilla larvae, Insect remains, Chironomids larvae, Ostracodes, Crabs, Detritus, Odonata, Euglena, Hemiptera and Molluscs (Table 4.9-3). These food items were compared with those collected during2008-2013 that found 18 food samples (Table 4.9-4).

Chi-square (X^2) test was used to tests for significant statistical differences in the diet within and between periods of sampling and found that:

Fish remains (X^2=2.333; df=5: $P<0.05$), Povillalarvae (X^2=28.429; df=11: $P<0.05$), Caridina nilotica (X^2=1.00; df=5, $P>0.05$), Ephemeroptera(X^2=7.00; df=5: $P>0.05$), Chironomids(X^2=114.93; df=3,$P<0.05$),Odonata(X^2=3.09; df=4: $P>0.05$),

Insect remains(X^2=8.857; df=4: $P>0.05$), *Crabs* (X^2=22.18; df=8: $P<0.05$).

Other food parameters observed in low quantities were Ostracodes, detritus and Euglena that were not significant.

Table 4.9-1: Catch rates (CAS) of *Mormyrus* k*annume* in upstream (ST10), Reservoir (ST11) and downstream (ST12) the UVN

	Years of comparison to the study							**Years of study (2014-2019)**					
Study sites	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**		**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
ST10	4.93±0.97	3.76±0.68	3.67±0.57	2.84±0.49	2.36±0.39	1.71±0.45		2.51±0.45	1.80±0.21	1.65±0.21	1.55±0.27	1.21±0.27	2.37±0.56
ST11	-	-	-	-	-	3.40±0.42		2.36±0.36	5.59±1.37	4.26±0.46	2.64±0.46	16.88±5.41	9.18±1.18
ST12	1.50±0.30	4.55±1.24	1.72±0.29	3.97±0.94	2.34±0.30	4.20±1.01		1.62±0.46	3.75±1.14	5.20±0.98	3.55±1.16	0.89±0.17	1.41±0.39

Table 4.8-3: The Catch rates and Value (CAS) *M. kannume* from various fishing gears sampled the UVN

	Others Fishing gears combined (Gillnet, Hook and line, long line and Cast net)		Basket traps	
Years	**Av.wt (kg)**	**Av. Price (US$)**	**Av.wt (kg)**	**Av.price (US$)**
		Studies between 2008-2013		
2008	6.69±2.52	0.61±0.04		
2009	4.39±1.38	0.49±0.03		
2010	4.05±0.81	0.62±0.02		
2011	1.94±0.49	0.34±0.01	1.60±1.40	0.41±0.00
2012	3.85±1.55	0.46±0.03	3.00±0.37	1.02±0.00
2013	2.57±0.56	0.77±0.14	5.10±1.22	2.79±0.00
		Current study of 2014-2019		
2014	1.79±0.50	0.42±0.03	3.20±0.61	1.84±0.34
2015	1.15±0.35	0.90±0.12	2.40±1.28	0.93±0.16
2016	1.88±0.40	0.77±0.10	7.10±1.28	2.43±0.21
2017	2.14±0.10	1.06±0.00	1.00±0.10	1.72±0.00
2018	1.90±0.21	3.99±0.00	7.30±0.00	1.83±0.01
2019	3.75±1.51	4.01±1.00	2.09±1.05	3.84±0.59

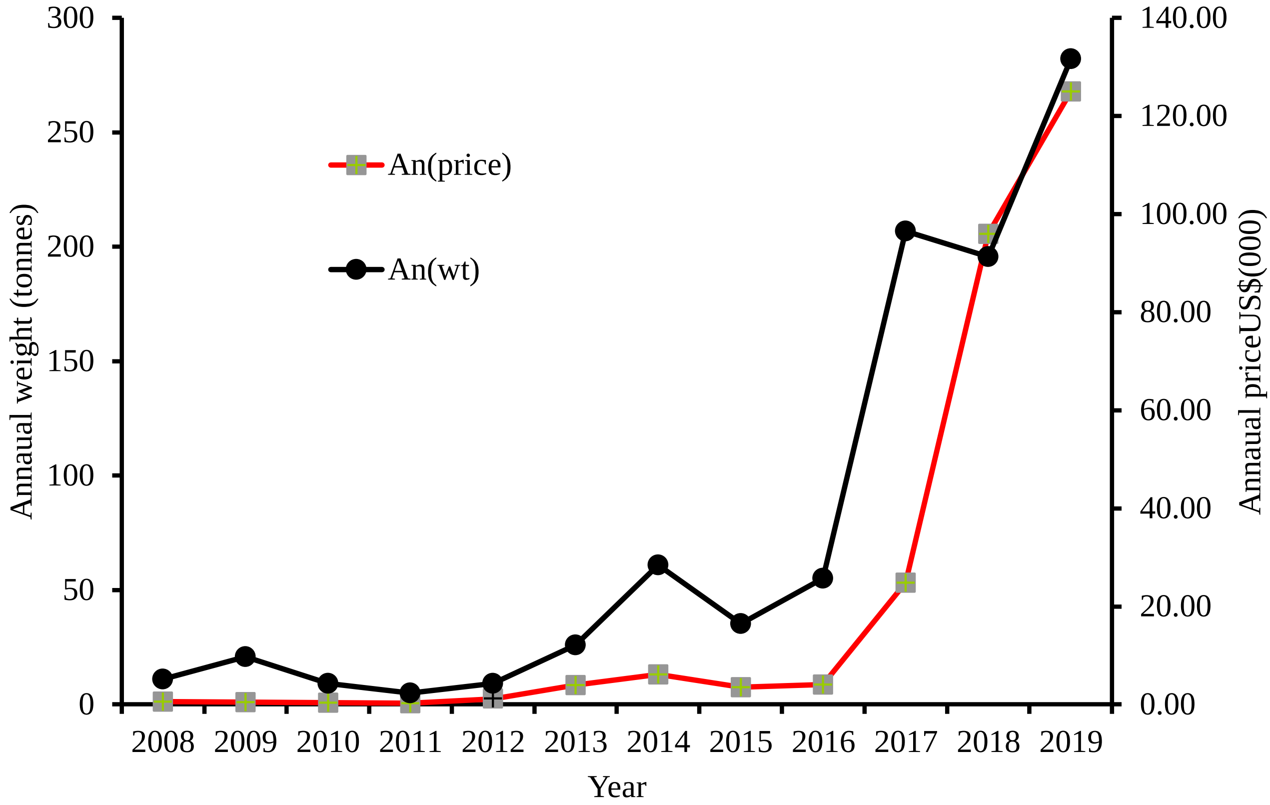

Figure 4.9-1: Annual catches and value of the *M. kannume* in tonnes and US$ (000) respectively, both in the year of study (2014-2019) and (2008-2013) of the UVN

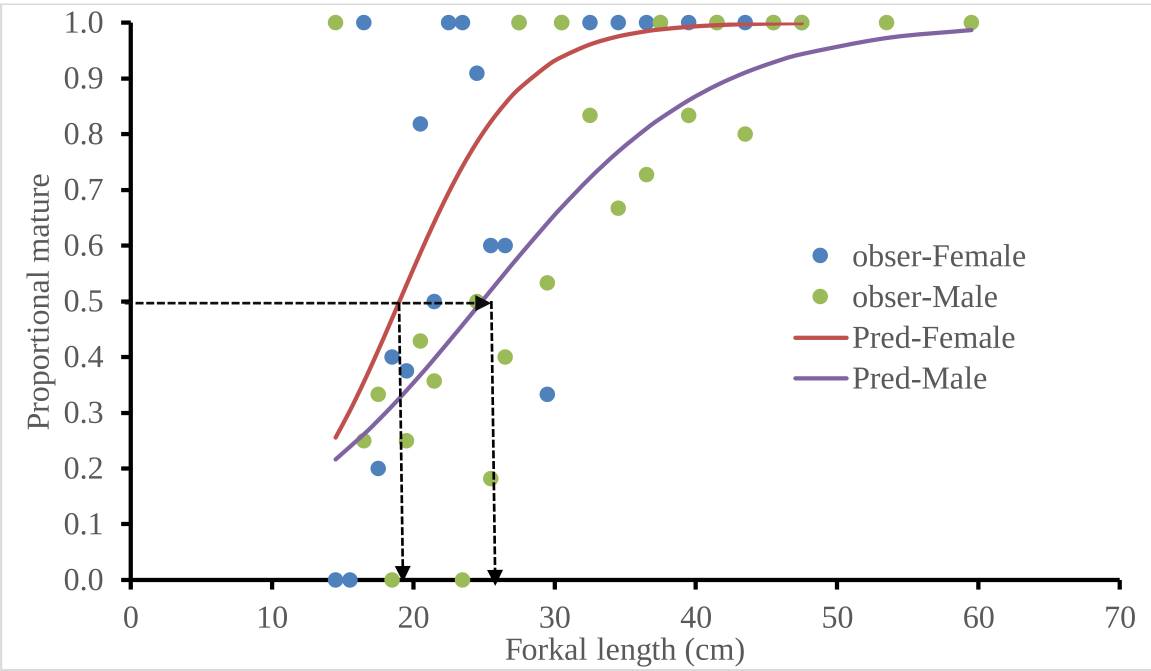

Figure 4.9-2: Length at first maturity of Males and Females *M. kannume*species from experimental gillnets data (2014-2019), Upper Victoria Nile.

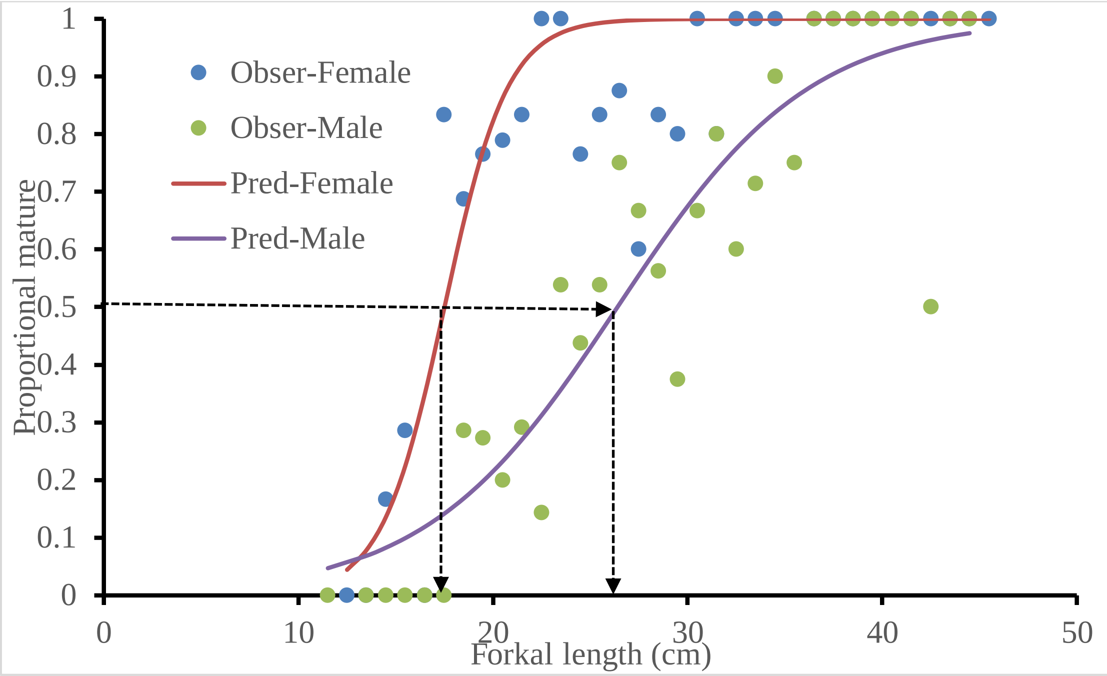

Figure 4.9-3: Length at first maturity of Males *M.kannume*species from experimental gillnets data (2008-2013), Upper Victoria.

Table 4.9-2: Food and feeding percentage indices *M. kannume* (2014-2019), UVN.

Year	2014	2015	2016	2017	2018	2019
Rastrineobola argentea	-	100.00	-	-	-	-
Fish remain	100.00	-	-	-	-	-
Povilla	54.43	-	45.57	-	-	-
Caridina nilotica	63.96	30.03	6.01	-	-	-
Chironomids	9.23	11.06	6.67	8.12	4.06	60.87
Ephemeroptera	9.21	6.39	-	2.88	-	81.52
Odonata	56.72	32.84	10.45	-	-	-
Hemiptera	100.00	-	-	-	-	-
Molluscs	-	52.81	-	47.19	-	-
Insect remains	21.86	13.47	-	10.78	53.89	-
Crabs	100.00	-	-	-	-	-
Detritus	0.41	-	99.59	-	-	-
Euglena	-	-	-	100.00	-	-
Ostracodes	-	-	100.00	-	-	-

Table 4.9-3: Food and feeding percentage indices of *M. kannume*(2008-2013), UVN.

Year	2008	2009	2010	2011	2012	2013
Rastrineobola argentea	-	-	100.00	-	-	-
Molluscs	-	-	87.27	12.73	-	-
Insect remains	22.74	20.52	11.05	23.03	6.45	16.21
Oreochromis niloticus	-	-	100.00	-	-	-
Fish remains	41.59	-	32.79	-	-	25.62
Ostracodes	-	-	-	-	100.00	-
Green algae	-	-	-	-	-	100.00
Povilla	19.07	33.91	-	10.44	16.80	19.78
Detritus	-	-	46.62	-	45.12	8.26
Leech	-	-	-	100.00	-	-
Caridina nilotica	-	79.26	-	-	6.19	14.55
Oligochaeta	-	-	26.09	28.26	45.65	-
Chironomids larvae	24.52	-	19.02	21.40	15.53	19.52
Chaobrus larvae	-	100.00	-	-	-	-
Odonata	-	-	-	29.20	31.42	39.38
Tricoptera	51.38	-	33.11	7.71	-	7.80
Ephemeroptera	-	-	21.11	46.92	22.58	9.38

The Chi-square (X^2) test for 2008-2013 used to tests for significant differences in the diet within and between samplingperiods of sampling showed that*Oreochromis niloticus* (X^2=0.333; df=1,$P>0.05$),Fish remains (X^2=29.121; df=9: $P<0.05$), Povilla larvae (X^2=106.0; df=15: $P<0.05$), Caridina nilotica (X^2=12.0; df=10, $P>0.05$). Ephemeroptera (X^2=12.8; df=8: $P>0.05$), Chironomids(X^2=96.76; df=17, $P<0.05$),Odonata(X^2=4.909; df=6:$P>0.05$), Molluscs (X^2=2.286;df=4,$P>0.05$), Insect remains(X^2=8.857; df=4: $P>0.05$.

Other food parameters observed in low quantities were Oligochaeta, Ostracodes, detritus and Green algae. However, thesedifferences were not statistically significant.Some types obtained in 2014-2019 study are different from those obtained in 2008-2018 study such as *Oreochromis niloticus*, Green algae, Leech, Chaobrus larvae and Tricoptera (Table 4.9-4).

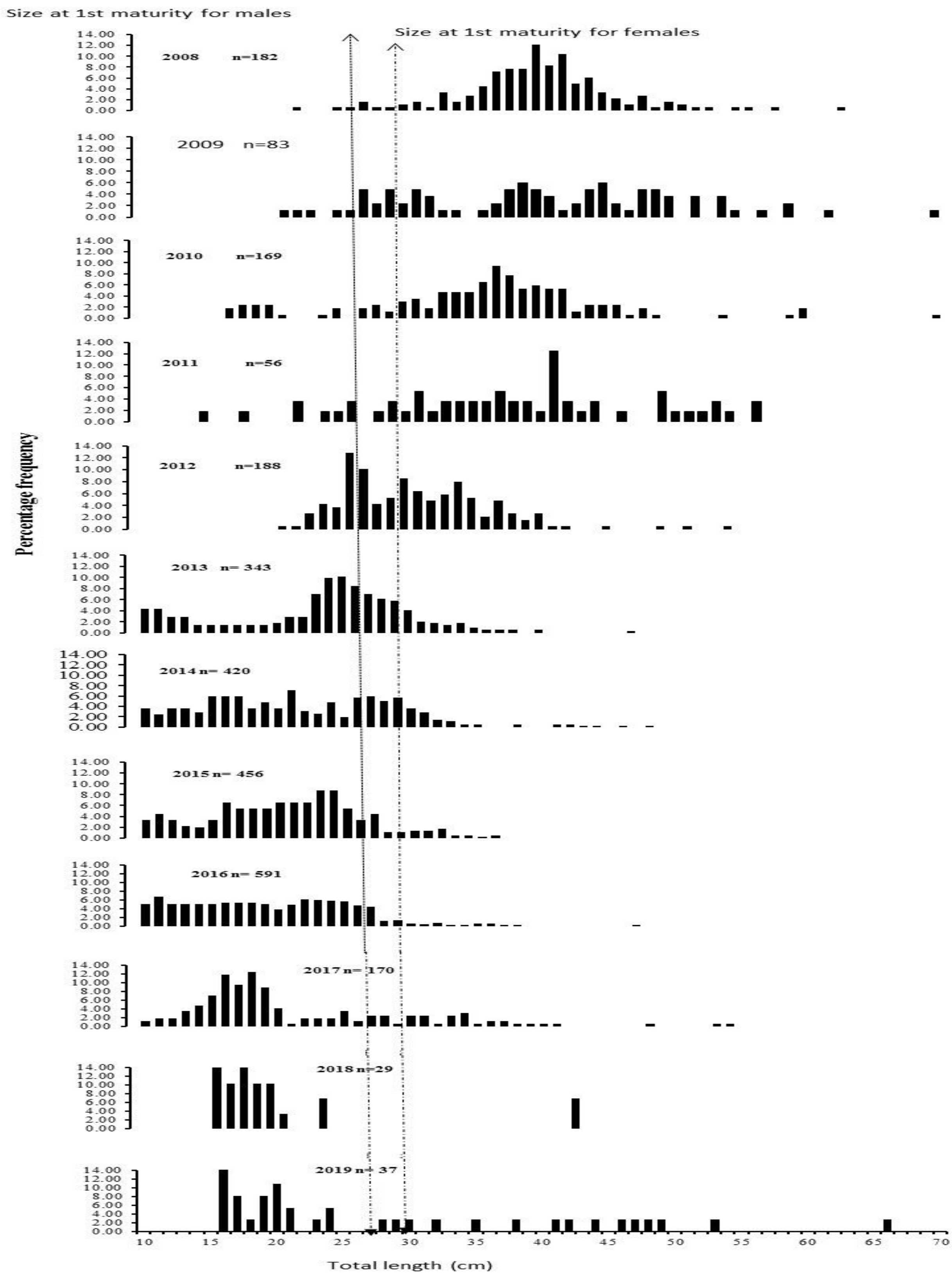

Figure 4.9-4: The size structure of *Mormyrus kannume* from the catch assessment, UVN

CHAPTER FIVE

DISCUSSION

This chapter focuses on discussing the results of the study.In particular, the chapter discusses the habitat quality, relationship between the physical parameters, habitat and fish structure and fish index of biological integrity,growth parameters, mortality, recruitment patterns, yield, catch effort characteristics, annul fish landings and the bait fishery of the *Mormyrus kannume,*Elephant snout fish.

5.1 HABITAT QUALITY AND ECOSYSTEM INTEGRITY

5.1.1 Physico-Chemical parameters of the Upper Victoria Nile

The pH changes recordedin stations (ST4), (ST5) and (ST6) which were higher than other stations, could be due to the effluents from the steel factories near the Bujagali dam in the Buikwe District Then fluctuations in the pH of (ST1), Naava (ST3), (ST2) at Kalange upper area of the Nile (ST8), (ST7) and (ST9) at Buyala on the lower area of the Nile could be linked to agricultural practices by farmers such as vegetable plantings that occur along the shores of the rivers up to the buffer zones. This kind of plantings has also left the place a bit bare such that during the rains siltation also occurs in these areas that could also be an attribute. In addition to that most the farmers use weed master (that contains 3,6-dichloro-o-anisic acid and 2,4-dichlorophenoxyacetic acid) as one of the chemicals to kill the weeds before planting; likely to be discharged into the river. In addition to that most of the buffer zones of these areas have been cleared up to the river, thus encouraging sedimentations. The National environmental Management Authority (NEMA), Uganda standards for pH range is (Upper NEMA Stdis 8 and Lower NEMA Std is 6) (NEMA, 1999). Studies from Uganda, India and Kenya document how acidic chemicals used in the manufacturing process have the potential of altering the pH of water (Turinayo, 2013; Yadat *et al.*, 2014; NaFIRRI Report, 2018; Orina *et al.*, 2018). The pH of the Upper Victoria Nile area ranged between 7.3-7.79, oscillating near neutral (Sharma *et al.* 2013). pH ranges between 6.5 – 9.0 are suitable for aquatic life support and are safe for drinking (6.5 – 8.5) (Orina, 2018). Therefore, the studyfrom the Upper Victoria Nile revealed that lacked extreme changes that could exert stress or destroy the ecosystem's aquatic life, including the fisheries.

Water temperature is an important factor that influences organisms' physiological activity moreso the aquatic life in an ecosystem. Temperature is influenced by stream morphology, soil hydrology, riparian vegetation, climate, and human activities (Multidisciplinary Science Team, 2000; Orina *et al.,* 2018).The Upper Victoria Nile, the upper stations of (ST3), Kikonko (ST1) and Makwanzi (ST2) had lower temperatures as compared to the stations (ST4), (ST5) and ST6) and the lower stations of (ST9), (ST8) and (ST7). This finding could be attributed tothe hydropower dam generators,increasing temperature to the lower levels of the dam. Temperature beyondor below the optimum (20-29 ˚C), leads to fish kills (Chaurasia and Tiwari, 2012). However, temperature variations are less likely to have a high impact on the fisheries' life span and other aquatic life. Other scientists document that the importance of temperature to large-scale distribution patterns in river assemblages have been seen in the longitudinal zonation of invertebrates and fishes along a river’s length. (Allan and Castillo, 2007;Olokotum, 2017).

Dissolved Oxygen (DO) plays a significantrole in fishery production. The mean DO concentration in (ST2) station was low compared to other sites in the upper scale of the river like the (ST4) and (ST1). Low DO concentrations can be attributed to intensive agricultural activities in the area, and other human activities causing a reduction in dissolved oxygen concentration (Orina *et al*, 2018; Olokotum, 2017; Chaurasia and Tiwari 2011). Reduced DO in aquatic ecosystems is attributed to the decomposition of organic substances and nutrients (Orina *et al.,* 2018; Rabala, 2002). Then the NEMA standards of DO is 3mg/l (NEMA, 1999).1

Therefore, the river's mean DO range was at a level tolerable by various fish species and other aquatic organisms in the ecosystem of the upper Nile.

The levels of Total nitrogen (TN) and Total phosphorus (TP) were generally high in all the sampled stations in the Upper Victoria Nileeven though the NEMA standards for these parameters range as follows; TN, 10mg/l and TP, 10mg/l (NEMA, 1999). Thefindings of the study could be attributed tothe agricultural activities in the catchment areas including the buffer zones of the river. Similar findings have been observed on river Kuja by Orina *et al.*, 2018 on the agricultural activities along the shores of the river causing effects on the riverine ecosystems including the fisheries. Studies showed that apart from (ST2) and (ST5), all other sites recorded very high TN and TP levels, which could be due to the use of inorganic fertilizers and manure for growing cabbages and other green vegetables. The sugarcane farms in the middle sites could also be a contributory factor. This corresponds to the works done by Orina, 2018 on River Kuja in Kenya. The increasing trend of nutrients downstream could be a result of cumulative concentrations from the catchment. However, the low values recorded at the (ST2) and (ST5) could be explained by the potential of macrophytes such water hyacinth and vossia to absorb these nutrients. Nutrient loading tends to increase in an aquatic ecosystem due to agricultural activities that create a causative effect in the system Increased nutrient loading and other contaminants within rivers could also emanate from surface runoff from the urban area and industrial discharges from the Jinja municipal, where the river originates from at the source of the Nile in Lake Victoria (Oguttu, *et al.*, 2007). Similar findings were reported by Orina *et al.*(2018), Rabalais (2002), Zaimesand Schultz (2002) and Kanda *et al.* (2015) in different ecosystems. Excess nitrogen concentration is also an indicator of manure or organic wastes (Wetzel and Likens, 2001; Isa, 2015).

There was a fluctuation trend in the TSS and electrical conductivity parameters in all sites that ranged from 3.1-4.3 mg/l and 98.6-104 us/cm as compared to the earlier studies (NaFIRRI, 2011) whose range was 2.5-2.9 and 100-102 us/cm respectively in the UVN. Despite of that variations of these parameters, they were in the ranges that could not cause harm to the aquatic life including the fisheries in accordance to the NEMA standards of 100mg/l for TSS and 1000us/cm for electrical conductivity (NEMA, 2020). Though studies undertaken by Priti and Khan (2011) and Orina*et al.*(2018)revealed that wastes and pollutants come from the areas occupied by human population and in agricultural areas.

There was a fluctuation trend of NO3-N (µg/L), PO4-P (µg/L) in all the sites sampled. The trends were 16.2-101.9ug/l and 12.3-29.7ug/l respectively in the current study as compared to 54.7-36.1ug/l for NO3-N and 20-31ug/l for PO4-P in 2011 (NaFIRRI, 2011) in the UVN. The NEMA standard for the above parameters stipulates NO3-N (µg/L), PO4-P (µg/L), 20, 000ug/l and 5,000ug/l respectively. Therefore, these parameters were in the ranges that could still support aquatic life and the fisheries in the UVN. Studies indicate that inorganic nutrients such as Nitrogen and Phosphorus are the major cellular components of organisms (Wetzel and Lakens, 2001). These nutrients also play a big role in primary production in the aquatic life system. Intense ecological interests in phosphorus stems from its central role in metabolism in the biosphere. This implies that under aquatic productivity, organisms in the water depend on nutrients, light and temperature. And most the nutrients they depend on are Nitrate and Phosphate. Nitrate is always in abundance but then Phosphate in always in limited abundance yet plays a central role in the aquatic ecosystem (Wetzel and Lakens, 2001).

NH4-N (ug/L) varied between 3.0-5.5 ug/l by years as compared to 1.5- 2.0 ug/l in the UVN studies of 2011 (NaFIRRI, 2011). The NEMA standards show NH4-N (ug/L) at 10,000ug/l thus the variations in the water parameters were within the tolerable range that could still allow fisheries production in the river systems as observed from the outputs. Despite of the ranges in the study, there is need to ensure that the is maintained low for the aquatic life. Studies have shown that tea factories and human intervention along Lake Victoria's shores could lead to increased pollution levels (LVEMP, 1995; Orina, 2018; NaFIRRI, 2018). This trend can have far-reaching consequences that will alwayslead to water quality threat to the rivers and lake ecosystems.

PCA results showed 60% variation Station 1 varied in No3 of 2016 from stations 7 and 9. NO3-N was highly variable during the years 2009, 2014, and 2016. The station downstream depended on influxes from station 1 upstream in 2016.The levels of NO3-N were high but were not reflected downstream. The reason could have been runoff from various parts on the sampling day .

Electro conductivity (EEC) increased downstream, suggesting nutrient spreading (nutrient spreading downstream to the river) (Olokotum, 2017). Therefore, the difference between station 9 and station 1 could be the distance from Lake Victoria. It is anticipated that nutrient spilling could be a measure of conductivity (Olokotum, 2017; Allan and Castillo, 2007). Hence, abrasion and eroding at the banks going downstream could have led to the spilling effect that may have increased downstream.

Nutrient levels TP/TN showed an increased trend downstream on spatial scale. This trend is likely the effect of the point source of N and P along the river associated with high agricultural activities with the villages of Naava (upstream)on the western bank of the river. The nutrient levels follow the sampling peaks that were programmed both in April and September on annual basis. The NEMA standards for TP and TN are 10,000 us/l and 10,000 us/l (NEMA, 1999), the results showed that the parameters were in the permissible ranges for the aquatic life including the fisheries.

5.2.0 The Habitat Quality Characteristics

The estimated HQI revealed that all the nine (9) stations were regarded as below good thus degraded. The observed variation could have been attributed to the change of the physical nature of the riverine ecosystem. The dam construction changed the ecosystem, thus the catch area in the UVN of the Bujagali area. The change of nature within a catchment and between catchments reported by Raven *et al.* (1998) is enhanced by agriculture, urbanization, roads, and mining. Hence the UVN show a deviation from the Vannote *et al*,(1980) principle. Stations like (ST3), (ST2), (ST8) and the 3 stations in the reservoir ascribed to integrity indices probably due to intensified dam construction at Bujagali dam, agricultural activities, and human settlements along the shoreline. Habitats play a big role in bank stability, reduction of floods,organic matter accumulation and alteration of the river with time and space (USEPA, 2000; Bassa *et al.*, 2019). Such circumstances were reported on the Kenya region, River Nzoia and River Kuja (Raburu and Masese, 2010;Orina *et al.*, 2018).

The HQI showed significant spatial variation in the reservoir stations, which was majorly due to the dam construction like in ST4, ST5 and ST6. The intensive excavations that were done in this area during the dam constructions contributed to such variations in the reservoir areas. The results for this study were compared with other studies conducted in other rivers and streams elsewhere as observed in Table 5.2-1.

On a temporal scale, the index indicated a significant variation in 2014 and 2019 though other years were relatively stable. Such changes could have been attributed to either human activities or the dam construction before it stabilisedin 2011. In 2019, the variations could beattributed tohuman activities along the river.Changes in the fish species diversity along the Bujagali area has been documented on Haplochromine's species and those that might become extinct due to dam constructions like the *Neochromis simotes*(Burnside report, 2006; NaFIRRI report, 2018). Sedimentation due to hydropower construction could have affected the riverine aquatic organism, including the fisheries and human activities along the shoreline, thus affecting the buffer zones of the river andthe fisheries spawning ground. Accumulations of sediments in the aquatic ecosystem have been reported to affect the breathing mechanism of fish, influencing their distribution, occurrence, and abundance, hence biodiversity (Vannote *et al.*, 1989; Balirwa *et al.*, 2005; Orina *et al.*,2018).

Table 5.2-1: Comparison of HQI in this study and that of other rivers and streams

Author	**Habitat**	**Range (%)**	**Comments**
Present study	Upper Victoria Nile –Bujagali area	25.86-32.89	From severely degraded to degraded
Orinal *et al.*, 2018	River Kuja; (Kegati to river mouth as from November 2016 to August 2017)	35.50-77.4	From severely degraded to partially degraded
Raburu and Masese,2010	Lake Victoria basin (R. Nzoia, Nyando and Sondu-Miriu Feb, Mar- Jul 2004)	22.00-60.5	From severely degraded to degraded
Bio habitat And Century Engineering,2016	Anne Arundel county (**Magothy*et. al.*,2015)**	61.31-98.01	From degraded to minimally degraded sites
Paul *et al.*2003	Maryland Wadeable streams (Piedmont class, Coastal plain and Highland class from 1994 - 2000)	15.43– 99.35	From severely degraded to minimally degraded sites
Diana *et al*.,2006	Southern Michigan (**Huron**, Raisin basin from 1999 - 2000)	33.30 – 79.3	From severely degraded to partially degraded

5.2.3 Fish Based Parameters in the UVN

5.2.3.1The Fish Community Structure

The results from the Upper Victoria Nile Bujagali area indicated that the ecosystem harboursmany fish species. The most dominant were *Lates niloticus* followed by *Mormyrus kannume.* With regards to trophic guild, carnivores were more abundant with (65.1%) omnivores (21.5%), and detrivores (16.9%), ST3 recorded the lowest catches compared to other stations. The low catches could have been due to agricultural practices up to the shores of the river bank.

The abundance and occurrence of fish species were high in upstream stations ST4, ST5 and ST6 compared to other sites. Most of the exotic species were found at the upstream stations from the reservoir to the Kalange area compared to the downstream stations of the river. This study, therefore, revealed that the fish community structure changed downstream. This trend was possibly due to the changes in food availability, substrate structure and water quality, and the water's speed below the dam. Alterations of water and habitat promote the loss of sensitive species while the tolerant and invasive species tend to dominate the ecosystem. This observation explains why the alien fish species tend to occur and dominate upstream as compared to downstream. The dam has also created an environment for fish migrations in the ecosystem (Yoshid *et al.*,2020). However, the Mormyridae family has shown low catches compared to other species, an indication of low management regime in the area.

On the temporal scale, the species identified were,*Bagrus docmac, Barbus altinialis, Clarias gariepinus, Coptodon zilli,* Haplochromine’s species, *Lates niloticus, Mormyrus kannume, Oreochromis niloticus, Oreochromis variabilis, Oreochromis leucostictus and Oreochromis variabilis, Protopterus aethiopicus, Rastrineobola argentae, Synodontis afrofisherie* and *Synodontis victoriae.* The Upper Victoria Nile play a big role as a hurb for the Haplochromines and species that are known to have declined. For instance, *Neochromis simotes* are known to have taken advantage of the ecosystem. It is in this ecosystem and specifically Kirindi region of UVN where such species are found and never observed in Lake Victoria. They are one of the species that were predated on by the Nile perch yet play a role in the food web (Atkins, 2006). *Oreochromis variabilis* and *Oreochromis esculentus* the original fishes of Lake Victoria are now seen only satellite lakes of Uganda (Ogutu-Ohwayo *et al.*, 2013; Twongo *et al.*,2006).Other fish species migrate for spawning in the river during the rainy season leading to an increase in biodiversity in both the lakes and rivers (Lowe, 1959; Kibara, 1981; Nkalubo *et al.,* 2018).Meanwhile the *Lates niloticus,* Nile perch a predator species has always remained as the dominant fish in most of the Victoria basin ecosystem including the UVN (Ogutu-Ohwayo *et al.,* 2013).

Fish diversity helps to explain the environmental condition of the riverine system and some characteristics of particular fish species such as habitat preference and resistance to environment-specific stress. For example, *Lates niloticus* that was the most dominant fish species with a percentage composition of 13.82%, *C. zilli* 7.92%, *B. altinialis* 2.67%, *M. kannume* 1.8%, *O. niloticus* 0.54% and *B. docmac* 0.41% are some of the tolerant fish species in the UVN meanwhile the then remaining haplochromines that contributed 72% fall under the intolerant category hence can be affected with environmental stress easily.Therefore, species richness and composition are important parameters for ecosystem stability and function (Bibi and Ali, 2013; Orina, 2018). The Upper Victoria Nile has diverse fish communities in the environment. Species richness was low in stations ST7, ST8, and ST9. These stations have poor habitats and other areasarebare, with sand shorelines that could not favour fish habitation. Agricultural activities on this shore are intensive compared to other stations. Such actions have led to sedimentation, thus low catches. Literature shows, that anthropogenic activities along the shore of the aquatic ecosystems affect the lives of the organisms of the system including the fisheries (Oguttu *et al.,* 2007, Diego *et al*., 2011; Olokotum, 2017).

Both the Spatial and temporal scales recorded fluctuations in the trends of the fish diversity indices. These scales indicated a significant difference between years and stations, suggesting that the ecosystem's changes due to the dam construction in the Bujagali area have affect the fisheries' biodiversity in the ecosystem.Studies in other rivers with hydropower constructed dams a shown that how aquatic organisms' composition and abundances tend to change in quantity and diversity due to alterations of the waters caused by the hydropower dams on these rivers (Orina *et al.*,2018; Yoshid*et al.*,2020).

5.2.3.2 The Fish-Based Index of Biotic Integrity

The fish-based index of biotic integrity indicated that the nine stations sampled had very poor to fair biological integrity. ST8 had the poorest FIBI score. The low result could be an attribute of the land use management especially the shoreline area. Studies conducted on rivers Kuja, Nyando, Sondu-Miriu and Nzoia revealed the land use activities influence the river's integrity (Orina *et al.,* 2018; Raburu and Masese, 2012). Therefore,increased population and human activities such as agricultural activities along the shoreline tend to lower the rivers' integrity,thus affecting the aquatic ecosystems of the upper Nile waters. The table below (Table 5.2-2) presents comparative research studies with a converted range of 0 to 5.

Literature showsthat few studies on the development of habitat quality and fish-based assessment tools have been conducted in the Lake Victoria basin system in Uganda. Therefore, information on habitat integrity is essential for formulating regulations used to restore and conserve degraded environments. The maintenance and restoration of the river's ecological integrity ensure that adequate resources are derived from it given thata pristine aquatic ecosystem provides sustainable intrinsic values and benefits to human communities (UNEP, 2016; Orina *et al.,* 2018). Besides water quality, flow regime, physical habitat structure and interactions among species are always altered. Natural vegetation and soil conditions have been altered, which has translated to increased water temperature, erosion, and siltation, leading to general habitat degradation. These changestend to affect the fish biota negatively due to impacts on the water quality. Constructed barriers across the river, habitat modification and water quality degradation have always affected fish migrations, fish diversity and abundance leading to a severe ecological and economic loss of both the fauna and flora in the riverine ecosystem (LVEMP, 1995; Balirwa *et al.*, 2003; Njiru *et al.,* 2008; Nkalubo, 2012; Orina *et al,* 2018).

Table 5.2-2: Comparison of FIBI in the Upper Victoria Nile study and other streams and rivers.

AUTHOUR	**FIBI area research**	**RANGE (0-5)**	**COMMENTS**
Present study	Upper Victoria Nile (Bujagali area)	1.8-3.5	Poor to fair
Orina et al., (2018)	River Kuja Kegati-river mouth Nov-2016-Aug-2017.	1.70-4.5	Very poor to good
Raburu and Masese (2010)	Lake Victoria basin (R. Nzoia, Nyando and Sondu-Miriu -Feb, March and July 2004)	1.70 – 4.6	Very poor to good
Bio-habitat and Century Engineering (2016)	Anne Arundel county (Magothy, Sevem and Salamanders - 2015)	1.67 – 3.67	Very poor to fair
Paul et al. (*2003)*	Maryland Wadeable streams (Piedmont class, Coastal plain and Highland class from 1994 - 2000)	1.00 – 5.00	Very poor to good
Diana et al. (*2006)*	Southern Michigan (Huron and Raisin basin from 1999 - 2000)	0.25 – 3.85	Very poor to fair

5.3.0POPULATION DYNAMICS OF THE FISHES OF THE UVN

5.3.1Growth Parameters for Nile perch (*Lates niloticus)*

Lates niloticus belongs to the family latidae that grow up to the maximum of 205 centimetre total length and weighs up to 200 kilograms in Lake Victoria (Bassa, 2011; Ogutu –Ohwayo *et al.*, 2013). The Nile perch (*Lates niloticus)*, is one of the commercial species in the Victoria basin. It plays a significant role as income and food to the riparian people in the basin lakes (Ogutu-Ohwayo, 1990; Balirwa, 1998; Njiru *et al.*, 2018). The Upper Victoria Nile is one of the systems within the Victoria basin region. The increased demand and supply of *Lates niloticus*regionally and globally has led to changes in its stock levels. Results from the upper Nile showed changes in catch estimates, growth and population structure of Nile perch. The catches of Nile perch in the upper Nile showed a fluctuation trend over time and space.The decline could be due tooverfishing in this ecosystem. The decline in the catches of Nile perch hasalso been observed in Lake Victoria due to its demand and supply in the export market in Europe (Njiru *et al.*, 2018).Results from the Upper Victoria Nile showed $L_\infty$of 93.45 cm TL compared to Lake Victoria Fisheries. Similarly, the Lake Victoria Nile perch has shown a drastic decline from 205 cm TL to 124 cm TL in the Kenyan waters (Manyala, 1990; Rabuor and Manyala, 1990; Nkalubo, 2010; Yongo *et al.*, 2018). The decrease in L_∞ has culminated in a sharp reductionin the numbers of fish above the slot size of 50–85 cm TL, based on the length-frequency distribution. (Njiru *et al.*, 2008; Yongo *et al.*, 2018). The reported fish below and above the slot size has continued being caught and processed, thereby confirming the slot size is hardly adhered to by both the fishers and the processors in Lake Victoria systems and the Upper Victoria Nile. The reductions in the sizes of *Lates niloticus*have been attributed to the illegal gears and methods used in the Nile perch fishery (Yongo *et al.*, 201**6**, Yongo *et al.*,2018).The fisherfolk in lakes Victoria, Kyoga have increasingly abandoned large-meshed gillnets in favour of small hooks on long lines which largely targets small size Nile perch. (Mkumbo and Marshall, 2015; Yongo *et al.,* 2018). Further, fishers use other illegal gears such as basket traps, small-sized gillnets, boat seines and cast nets that catch small Nile perch from the Upper Victoria Nile. The availability of Nile perch <50 cm TL from the sampled data and variations in the b value confirms an intensive illegal fishery in the upper Nile that has affected the Nile perch stock.

The length at infinity L_{∞} of *Lates niloticus* wasestimated to be lower than in Lake Victoria at 93.45 cm TL compared to 205 cm TL (Table 5.3-3) respectively (Rabuor and Manyala, 1990).The two environments are different. The Lake provides a lacustrine environment in which environmental variables are less stressful than the riverine environment of the upper Nile. Fish are known to attain different maximum sizes in different environments. For example, the asymptotic length in different lacustrine environments is not the same. For example, in Lake Chad, the fish attains a different asymptotic length than in Lake Victoria (Hopson, 1972).

Further, it was been observed that the Nile perch attains and matures smaller sizes in the dam (Getabu pers.com). In the Upper Nile ecosystem, environmental stress emanates from anthropogenic activities thatinclude unsustainable agricultural practices. Industrial and urban effluents stress the environment due to the smaller volume in the river the impacts on the growth of fish and other aquatic organisms, thus limiting the maximum size the organism can attain (Paterson *et al.,* 2009;Abowei*et al.,* 2010; Kalhoro *et al.,* 2017).

The Nile perch is a predator that has shifted in the diet,which predominantly consisted of a protein-rich diet consisting of fish) (Njiru *et al.,* 2004; Yongo *et al.,* 2018) including the juvenile Nile perch. Thisdietary shift could have led to improved growth performance and maintenance of large specimens. Inthe late 1960s to early 1990s, more than 90% of the Nile perch diet consisted mainly of fish (Ogutu- Ohwayo, 1990; Yongo *et al.,* 2018). Even the recent studies indicated that Nile perch feeding habits less on the freshwater prawns (*Caridina niloticus* Roux), then more on the haplochromines, the juvenile Nile perch, and few cases of the Barbus species, probably indicating high feeding diversity of this fish as a predator. Diversified feeding could have led to an increase in the Nile perch's length and longevity in the upper Victoria Nile. The intensity of exploitation could have contributed to fast reduction in the Nile perch's maximum sizes in the Upper Victoria Nile.

In addition, the total mortality (Z) of 1.79 yr^{-1} and natural mortality coefficient (M) of 0.79 yr^{-1} reported in the present study is comparable with the value of 1,65 yr^{-1} and 0.81 yr^{-1} reported by Bassa (2000) in the study on Nile perch in Lake Victoria, Uganda. Also close to 2.92 yr^{-1} (Z) and 1.50 $yr^{-1}$is a study reported by Njiru *et al*,(2008) in the Lake Victoria, Kenyan waters. Natural fish mortality is attributable to the factors associated with fishing, including predation, competition, cannibalism, diseases, spawning stress, starvationand pollution stress (Yongo and Outa, 2016;Yongo *et al.,* 2018;) and intensive exploitation rates by the fishers.

The current study reported a $L_{50}$of Nile perch of 30.3 cmTL and 40 cmTL, lower than that reported by Nkalubo (2012) and Yongo *et al.*(2018), suggesting that the fishing gears are catching high proportions of immature fish in the Upper Nile. The recruitment peaks in March and August coincided with the rainy seasons along the Upper Victoria Nile. This observation was in agreement with the recruitment peaks observed by Yongo *et al,* 2018 in Lake Victoria's Kenyan waters.Thus, the recruitment of Nile perchis influenced by food availability and favourable environmental conditions. Rabuor *et al.* (2003) and Yongo *et al.*(2018) observed the highest peak for recruitment of Nile perch in November, December and January in the

Nyanza Gulf of Lake Victoria, with a minor in June, indicating the recruitment of two cohorts per year. The impact of population parameters on the biomass and yield reflected in the Beverton and Holt's yield –per recruit model (Sparre and Venema, 1989). The current mortality rates the observed exploitation rate E of 0.62 is higher than the optimum sustainable yield ($E_{0.5}$) of 0.278 but not much different from the maximum yield (E_{max}) 0.474 and slightly with economic yield ($E_{0.1}$) 0.306. These results agreed with Yongo *et al*, (2018) who reported that the Nile perch population in Lake Victoria's Kenyan watersdepicted how the fishery exhibited some kind of demographic equilibrium. In general, the Upper Victoria Nile is experiencing a high decline of the Nile perch. Thus, managing this fishery needs strict adherence to the slot size of 50-85 cm TL, restrictions on illegal gears, enforcement and fisheries control and surveillance working with the local leaders at the river ecosystem's landing sites.The length catch curve indicated that immature fish experienced mortality and this mortality was predominantly fishing mortality (F). The number of older fish, which were recruited above 5 years were few. Hence most of the mortality is on fish that have not been recruited into the fishery.

The recruitment patterns of Nile perch depicted two peak recruitments in a year. The first recruitment peak corresponded to the second quarter of April to June during the long rain periods.The second recruitment occurred around August to September during the short rains. This observation suggested that Nile perch recruits into the fishery during the year's long and shorter rains periods (Yongo *et al.*, 2018).

The yield per recruit obtained was too low at 0.06, supporting the observation that there was heavy fishing mortality on juvenile fish. Under sustainable exploitation, the yield per recruit should be the size of Nile perch that is mature(3500-5000 grams). However, this size should be lower in the upper Nile because it is expected that the fish cannot attain such big sizes as in Lake Victoria. Comparing the growth parameters for *Lates niloticus*on the Upper Victoria Nile done in other studies in various water bodies (Table, 5.3-3 and 5.3-4) depicted variations over time and space.This study indicated that human exploitation is high as compared to other drivers, implying that the level giving maximum sustainable yield has been exceeded and that there is urgent need to check the sustainable exploitation of *Lates niloticus* in the Upper Victoria Nile in the East African region.

5.3.2Growth parameters for *Oreochromis niloticus* and other tilapiines

In the UVN,*Oreochromis niloticus*estimated at L_∞ 47.25 cm TL and K was 0.890 per year.This species' growth parameter in the UVN was compared with the Lake Victoria system that recorded Asymptotic length of L_∞ 53.9 cm TL with the K= 0.50 per year (Njiru *et al.,* 2008;Njiru *et al.,* 2018). The longevity of the Nile tilapia $t_{max}$was 4.13year compared to 6 years on Lake Victoria. The *O. niloticus* like the Nile perch could be experiencing the same environmental stress in the UVN with regards to growth rate and sustainability.

In addition to that the Total mortality (Z) estimated at 2.80 year^{-1}, the fishing mortality was (F) of 1.39 year^{-1}, natural mortality (M) 1.41 year^{-1} and the exploitation rate (E) 0.50. These parameters were compared with the same species from the Lake Victoria basin that found the Total mortality (Z) 2.83 year^{-1}, the fishing mortality (F) 1.92, natural mortality (M) 0.91 and the exploitation rate (E) 0.68. The attributes in this fish's changes could be the same as mentioned in the Nile perch fishery in the upper Nile since the entire share the environment. The variations in these fish species do happen on other fish species such as the *Oreochromis variabilis* and other fishes.

Oreochromis variabilis, popularly known as Victoria tilapia is one of the native species in the African lakes and rivers (Ogutu-Ohwayo *et al.,* 2013, Ogutu-Ohwayo, 1984). This species is observed as one of the endangered species on the African continent (Mathias *et al.,* 2016).This fish speciesused to be in the Kyoga basin lakes, the Victoria basin ecosystem and other areas of the ecosystem in the African region is no more today. The fishspecies recorded L_∞ of 36.75, W_∞= -0.301 and curvature parameter (K) of 0.44.The growth performance indices asymptotic length (L_∞) and asymptotic weight (W_∞) were Ø= 2.774 per year and Ø= -0.301 per year for from the riverine of the UVN waters. The mortality rates recorded values of total mortality parameters of Z=1.74 per year, F of 0.79 with the exploitation rate of 0.45. The results show that the exploitation rate is high, and this exploitation is one of the drivers that led to low catches of this species in the upper Nile. Further, Total mortality coefficient (Z), natural mortality (M), fishing mortality (F) and the exploitation ration (E) are vital for determining the status of the fishery. These parameters are used for establishing the level of exploitation of the fishery (Abowei *et al.,* 2009; Kalhoro *et al.,* 2017).

5.3.3 Length- weight relationships for the major fish species of UVN

If an animal is growing isometrically and doubles in length, its weight will increase in relation to the increase in volume; that is by 8 (or 2^3) (King 1995; Asadi *et al.,* 2017). The commercial fish species sampled from the UVN such as, *L.niloticus, O.niloticus*and *O.variabilis* ,data showed that all these fishes were growing isometric; hence their growth in weight and length is proportionate.Therefore, *L. niloticus,O. niloticus* and *O. variabilis* fish species show increase in all dimensions at the same rate, if managed properly, fishery production will increase in the ecosystems of the UVN. Literature has shown that knowledge of length-weight relationships is an important tool for the adequate management of any fish species which have been applied in the assessment of fish stocks and populations. It is also useful in local and interregional morphological comparison of populations (Asadi *et al.,* 2017).

5.3.4 Food and Feeding Interactions of the major fishes of the UVN

Results from the UVN indicated changes in the diet of the Nile perch. The juveniles ranged from 7.4-18.5 cm TL. The gut contents comprised more of fish remains compared to other food items, while those from 19.0-64.0 cm TL fed on more on*Caridina niloticus* than other food contents, which agreedwith findings on feeding habits of the Nile perch from other studies (Njiru *et al.,* 2018). The only difference we observe is that in the UVN, the Nile perch seem to be having a change in its feeding habits dependingmore *onCaridina nilotica,*an indication of a reduction of the fishes in terms of catch that could attribute to theseoccurrences.

O. variabilis species depended more on the Macroinvertebrates, suggesting that the changes have occurred in the Nile tilapia species feeding habits despite the fact is an herbivore (Balirwa, 1998).The low abundance of the aquatic organisms that are taken as food hasalways led to the fish migration patterns (Lin, 2010; Nkalubo *et al.,* 2018).River modification leads to low macro-zoo benthos organism, thus affecting the fisheries communities such species that are herbivorous (Sekiranda *et al.,* 2004; Vincent *et al.*, 2012; Ngupula, 2013).

Table 5.3-3: Comparison of mortality parameters of *Lates niloticus*in UVN waters with other studies from different fields and areas of the worlds.

Source	Areas	L_∞	K	Z	M	F	E	t_{max}	Ø’	L50Male	L50Female
Present study	Upper Victoria Nile (UVN)	90.30	0.36	1.71	0.65	1.06	0.62	8.1	3.468	30.1	40.3
2008-2013 upper Nile	Upper Nile , Bujagali area	78.75	0.55	2.49	0.89	1.60	0.64	5.3	3.533		
Rabuor and Manyala, 1990	Winamu Gulf, Lake Victoria 1990	205	0.19	4.725	0.34	4.38 5	0.92 8				
Njiru *et al*.2008 (1998-00)	Lake Victoria Kenya	204	0.21	2.92	1.50	1.42	0.80	14		60	62
Njiru *et al*.2008 (2004-2005)	Lake Victoria Kenya	133	0.25	3.40	0.58	2.92	0.86	12		54	50
Nkalubo PhD Thesis 2010	Lake Victoria	160	0.17					7.5		56	80
Bassa S.,2000	Lake Victoria			1.65	0.81	0.84	0.95				
Yongo *et al*.,2018	Lake Victoria, Kenya	124	0.22	0.96	0.42	0.54	0.57		3.53		

Table 5.3-4: Comparative study of length –weight relationship parameters of Nile perch

Reference	Research areas	a	b	R2
Present study	Upper Victoria Nile (UVN), Bujagali area	0.008778	3.10052	0.984
2008-2013	UVN, Bujagali area	0.100269	3.0072	0.9552
Witte and Densen 1995: EAFFRO 1973-1975	Tanzania part of Lake Victoria	0.0066	3.155	
Witte and Densen 1995: HEST Team, 1988-1990	Mwanza Gulf and Speke Gulf Lake Victoria	0.696	2.09	
Bassa S. MSc. Thesis 2011	The effect of hook and size on the catch rate and size of the Nile perch in the Napoleon Gulf Lake Victoria, Uganda.	0.0058	3.2005	0.9532
Akumu J.Msc.1999	Spatial and Temporal Distribution on Fish stocks in the Napoleon Gulf of Lake Victoria	0.0027	2.97	0.95
Nkalubo PhD Thesis 2010	Life History traits and growth of Nile perch in Lake Victoria, Uganda: Implications for Management fishery.	0.0072	3.132	0.9900
Yongo and Outa, 2016	Lake Victoria, Kenya	0.0104	3.641	0.981
Ogutu-Ohwayo, 1999	Lake Nabugabo	0.0104	3.03	0.966

5.4.0 Discussions of the Trends In Fishes Catches And Effort Of The UVN

5.4.1 Fishing effort of the fishery of UVN

The changes in fishing effort on the Upper Victoria Nile have not been well documented. The consistency and comparability of historical data are uncertain. The major concern was disparity in data collection methodsbefore the improved and standardized protocol provided in LVFO (2007a) and LVFO (2007b).

Fishing effort and catchability coefficients measure fishing mortality whose variations can be used to assess trends in stocks of natural populations (King, 1995, NaFIRRI, 2018). Fish Catchment assessment Surveys (CAS) have been conducted on the UVN by assessing fishing effort and fish catch trends to estimate fish yield because fishing is an important socio-economic activity for riparian communities. Besides estimation of fishery yields, information that guides the formulation of sustainable management advises alongside development projects such as dam construction provided. For example**,** Scudder, (1991),attributed reduced fish yields in the Black Sea and the Sea of Azov to impoundments on the Danube, Dnieper and Dniester rivers in Europe. Thus, monitoring of fish effort and catches can help to detect environmental concerns that might require mitigation measures to ameliorate the negative impacts of river ecosystem function and loss of aquatic biota, particularly fish.

Results of this studyshow that two types of boats used for the activitiesnamely,parachute and Ssese flat pointed one end. The catch effort data from UVN revealed 993 Ssese flatboats during the period 2014to 2019 compared to 399 from2008 to 2013. The increase in the numbers of fishing boats is probably due to periodic changes in the fish catches in the UVN. Such trends in the changing fishing effort could be attributed to fishers' tendencies to migrate in areas for better catches (NaFIRRI, 2018; Bassa *et al.*, 2019b). Such movements help fishers to maintain their livelihoods in form of employment, food, and nutritional security.

The effort showed thatbasket traps obtained 30% followed by hook and line 22% and the least was monofilament boat type with 0.10% in the sampled period that were compared with the later years of 2008-2013, Hook and line was 20.5% followed by 19.5% and the least was boat seines with 0.41%.However, the fishery was dominated using small-sized mesh gill nets of 25.4- 76.2 mm that is less than the 127 mm legally acceptable mesh size for gill net fishery in the Upper Victoria Nile (Fishing rules, 2020). This observationreflected the absence of large fish in the stocks. Secondly, due to the exploitation of fish in the upper Nile, fishermen have changed to other fishing gears to catch the remaining fish stocks of other fish species that have not been targeted. To support these observations, there is a two-year circle of increase and decrease in catch landings and catch rates of different fish species like *Lates niloticus* and *Oreochromis niloticus*. Once a fish stock has been exploited, it declines to a minimum, and fishers abandon that fishery and go to another terrestrial fishery. Once the fishery recuperates, the fishers come back when the catch rates are good and continue harvesting the fish until the fishery collapses. After the collapse of the fishery, fishermenabandon the fishery for other activities. These observations show that there is little management in the fishery of the upper Nile (Personal observation).

Fifteen (15) fish species were obtained during CAS from the UVN.However, *Lates niloticus* still dominated the fishery as compared to other species. Besides *Lates niloticus*, the *O. niloticus*,*M.kannume*wereharvested from the fishery. The size structure of these fisheriesshows small-sized fishes harvested from the fishery. This finding is an indication of the destructions done by the non recommend fishing gears thus leading to these fishes mature at smaller sizes in the UVN. Hovgerd and Lassen (2008) have shown that the choice of fishing gear at a particular fishing ground is influenced by the target fish species, the cost of fishing gear, the catch per unit of effort(CPUE), the habitat and suitability of the gear with respect to that particular site. Fishers often shift between fishing gears in response to seasonal variations in catches of the target species; thus,the fishers can use particular fishing gears when catches of the target species are high and can abandon it when catches go down (Lwenya *et al.*, 2009; NaFIRRI, 2018).The increase in the effort could be attributed to the increasing significance of the *M.kannume* bait fishery. The *M.kannume*species has gained importance as bait for the large size high valued species such as *L.niloticus*, *P. aethiopicus* and *C. gariepinus*on lakes Kyoga and Victoria currently faced with heavy exploitation.The species appears to be experiencing growth in overfishing thus the sustainability implications of the heavy exploitation to their fisheries more especially when observations see that majority of the fisheries exploited are below the L_{50} (Figures 4.9-2 and 4.9-4) requires urgent regular monitoring. In addition, the UVN is a multi-species fishery, and if well managed,i.e., reduction in fishing effort promoted, could lead to high yields. In addition to the management regimes, it could have been of values if fish breeding habitat type were researched on in the UVN to determine the variations in fish diversity and gazettements of such areas for fish productivity.

Annual fish catches recorded variations in catch estimates with the lowest observed in 2017 (156.88±5.44) and the highest in 2019 (1,072.41±164.46) tonnes.There was inconsistency in the fish production in the upper Nile. This fluctuation was anticipated to increase the utilization of the illegal nets below 5 inches and other gears such as the cast nets and basket traps that are not commensurate to the fisheries regulations and law (Fishing rule, 2020). Then the annual production of 2019 was higher compared to others years this could been an attribute of increase in the rains in that year. This follows the Serial Discontinuity conceptthat promotes primary productivity in aquatic ecosystem including the fisheries.

5.5.0 Assessment of the Impacts of the Bait Fishery (*M. KANNUME*)

The Upper Victoria Nile is one of the productive ecosystems in the Victoria basin. It is multispecies dominant and the riparian population depends on it as a source of income and food. For decades, the riparian communi**ties**have been harvesting fish as food and for incomegeneration.Until recently, this kind of methods changed with the introduction of hunting for bait for the Nile perch in Lake Victoria that changed the fishery in the UVN. Currently, the Elephant snout fish (*Mormyrus kannume*) is one of the fish species harvested from the UVN as bait for the Nile perch. Since thebasket traps are used as the core methods, the Elephant snout fish are caught alive with minimal mortality rates.

Both men and women now consume the Elephant snout fish, which was historically reserved for men (Okedi, 1964). Besides that intensive exploitation using basket traps on the Nile, the exploitation levelare unknown.

The stocks of this fishery are at threat.Results showed fluctuations in mean catch rates from 2008 to 2019.The increasing annual beach revenue shows how the *M. kannume* has gained valueas bait for the Nile perch.The exploitation is supported by the information of the open-access nature of the small-scale fisheries, widely scattered by nature that has been led by fishing communities and landing sites, making it difficult to regulate fishing and related activities (Asio *et al.*, 2014; Bassa *et al.*, 2014;Kolding *et al.*, 2014). The significant variation indicated how the riparian people along the shores of the river have exploited the fishery in the Upper Victoria Nile as bait and food. Besides, itis likely to be attributed to the exploitation of the fishery by using basket traps, evolving from the traditional gillnet setting on the Nile River.Literature indicates that bait in the Victoria basin has changed the fishing methodleading to a depletion of the ecosystem (Gosse, 1984; Mkumbo & Mlaponi, 2007;Chitamebwa *et al*., 2009;Bassa, 2011).In terms of size structure, the fishery is observed to mature at a smaller size than findings from the literature (Table 5.3-3 & 5.3-4). These sizes have been decreasing on a temporal basis indicating the intensive harvest of the Elephant snout fish in the Upper Victoria Nile.

The growth parameters indicated a significant difference in spatial scale in the Upper Victoria Nile. Fluctuations in these parameters were observed in the total mortality with yield per recruit analysis (knife–edge selection Isopleth). The Exploitation rate, K, t_0, W_∞, Ø', Ø, M, L_∞ indicate the fishery utilization in the riverine ecosystem needs attention from the fisheries managers. Information from the Caspian Sea using the growth parameters, mortality rates, and yield per recruit, biomass and MSY using length-frequency analysis has helped advise managers to keep fishing to better levels and, thus, sustainable yield (Gheshalghi *et al.*, 2011; Ragheb, 2016). This approach equally applies in the Upper Victoria Nile.

Besides the growth parameters, sex ratio identified as an important tool when choosing freshwater fish species for farming (Ragheb, 2016). In such a circumstance, sex ratio needs to be incorporated into the production more especially on resource allocation between female and male fishery (Ragheb, 2016). In the Upper Victoria Nile, the ratio varied 0.5:0.4 for males to females as compared in the Nile waters of Egypt, Damietta branch of the Nile with 1:0.8 respectively (Ragheb, 2016) an indication of how these fishes are maturing at a smaller size in this ecosystem.

It was observed that the *M. kannume* mainly fed on the Macroinvertebrates like Ephemeroptera, Povilla, Caridina niloticus, Chironomids, Chaobrus larvae, Ephemeroptera, Odonata, Tricoptera, Hemiptera and the Insect remains; plus low quantities of the Molluscs, the leech and the Oligochaeta. The feeding habits of the fish indicated a significant variation in all sites sampled.

Table 5.3-0-5: Estimated growth parameters and natural mortality for *M.kannume* in different regions of the Nile by various authors

Author	Location	K	L_{∞}	t_o	W_{∞}	Ø'	Ø	M
El-Etreby (1985)	Lake Nasser	0.061	156.260	-1.137	24927	3.170	1.720	0.160
Aly (1993)	High Dam reservoir	0.147	96.100	0.029	8482	3.130	1.790	0.320
Ahmed (2007)	Nile at Assiut	0.148	67.940	-0.836	2683	2.830	1.520	0.350
Khallaf and Authman (2010)	Bahr Shebeen Nilotic Canal	0.100	79.670	-1.634	6050	2.800	1.520	0.270
	Damietta branch of Nile							
Evelyn Ragheb (2016)	Egypt	0.141	80.650	-0.271	4151	2.960	1.560	0.340
Present study	Upper Victoria Nile	0.15	69.30	-1.1411	4017	2.858	1.579	0.400

Table 5.3-0-6: Estimated length-weight parameters and coefficient of conditions (K) for *M.* in different regions of the Nile obtained by various authors

Author	Location	A	B	R^2	Condition factor
Forkal length					
Solima (1994)	Nile at Sonhag	0.0120	2.934	0.998	0.97
Khallaf and Autham (2010)	Bahr Shebeen Nilotic Canal	0.0070	3.033	0.998	0.78
Evelyn Ragheb (2016)	Nile at Assiut	0.0060	3.063	0.997	
Present Study	Upper Victoria Nile	0.0131	3.000	0.932	1.06

Feeding indicated that these fishes are bottom feeders.The organisms identified from the gut contents were from the bottom strata of the water system. Modification of the water system andthe creation of barrages leads to a low density of macroinvertebrates in the ecosystem. A change in the riverine system drives thischange, as in Vannote *et al.,* (1980) river continuum theory, due to the microbial biomass and modified detritus that serve as a food source for detrivores (both invertebrate and vertebrate) common in streams and rivers (Wanda *et al.,* 2001). This change could have led to the low catches of the *M. kannume*and the intensive exploitation by the fishers.

CHAPTER SIX

CONCLUSIONS, RECOMMENDATIONS AND SUGGESTION

6.1 SUGGESTION

The status of water quality and the level of nutrients (physico-and chemical) indicate conducive environmental conditions for survival, reproduction, and fish growth. Therefore, any changes in the ecosystem needs to be managed by the riverine users.

The non-native fish species contribute to extinction especially with low water quality (Miller and Williams, 1989), suggesting thatthe river's biota is also at stake due to the presence of introduced fish species like *Lates niloticus* and human activities that affect the riverine ecosystem thus, ecosystem integrity requires conservation measures for restoration, conservation, and management.

Secondly, the results indicated that the Upper Victoria Nile had a diverse fish species with a habitat quality ranging from poor to fair according to the FIBI in the UVN. The studyfound that human activities play a role in retarding the ecosystem of the river, leading to significantly reduced dissolved oxygen, increased nutrient concentration, decreased habitat quality and the fish community structure downstream. These results revealed variations in the findings. Some parameters reject the null hypothesis at spatial yet accepted at temporal (Appendix 12). The correlation analysis indicated that a fish-based index of biotic integrity used to predict the habitat quality, abundance and diversity of fish and a habitat quality index used to relate the fish species richness, abundance and evenness index of biodiversity. Hence, the integrity indices were largely dependent on the activities adjacent to the river.

The population structure of the riverine fishery shows that falls under the small-scale fishery provides income, offers employment reducespoverty and contributes to food security and nutrition security. However, UVN small-scale fishery is under-valued with no management program geared to it. A continuous increase in the riverine disturbance will fail to fulfil its socio-economic importance and may lead to its eventual collapse. Therefore, a riverine resource utilization policy should be developed, drawing its contents from the immediate environment and adapting to local conditions that arealigned with the range of livelihood functions performed by the riverine fishery in the Upper Victoria Nile. This action will lead to biodiversity conservation and sustainable utilization of the resource.

This study gave an insight into the fisheries' status on the upper Nile, Bujagali area suggesting the annual production that show most of the fishes 70% are small sized fishes, which earn low market value. Besides management of the large sized fishes, therefore, is **to** incorporate post-harvest handling means to add value to the small fish products (*Rastrineobola argentae*) to increase their market value and efforts to reverse the declining trend of large species.

The Upper Victoria Nile's estimated production has a high regeneration or turnover rates and often dynamic and calls for a reasonable investment in regular monitoring to provide adequate information to inform management decisions.

This study gives a holistic approach to the bait fishery more so the Elephant snout fish. Results indicate increased revenue and catch in the Upper Nile. The increased catches are of smaller-sizedfish;thus, fishes mature at lower sizes to ensure survival for the fittest- “a tragedy of the commons in the fishery” (Hardin, 1995;Ogello *et al.,* 2013) that needs attention for sustainability and management.

6.2 RECOMMENDATIONS

The following are the recommendations for the study to be undertaken.

- There is a need to improve and maintain ecosystem integrity to promote sustainability of river resources both the aquatic organisms and the fisheries in the Upper Victoria Nile.
- The Nile perch is maturing early in the upper Nile as observed in the fish species' length at infinity. The growth rate was observed in other fish species such as the Nile tilapia and *MormyrusKannume*. Therefore, a slot size of 50-80 cmTL for the Nile perch should be adhered to for the fishery's sustainability.
- Measures on other upper Nile fish species need to follow the length and first maturity of these fishes for sustainability and fishery management.
- Regulation of the *Mormyrus kannume* fishery thus use suitable fishing gears and following the fishing rules need to be adhered too (Fishing rules, 2010).
- It would be necessary for the Upper Victoria Nile's fisher folk to have a viable alternative livelihood to reduce pressure on the *M. kannume* harvest on the river system.
- Aquaculture of *Mormyrus kannume* could be the best alternative to meet the demand and supply of the bait fishery on the Lake Victoria basin.

6.3 SUGGESTIONS FOR FUTHER STUDIES

- Ecologists need to develop standardized criteria for habitat assessment and biomonitoring to compare results in both studies and future times.
- There is a need to have constant monitoring of the changes in the water levels in relation to the fish biodiversity and habitat integrity for sustenance.
- There is need to have fish breeding zones (Mapping critical habitats in the UVN) in the UVN for gazettement, conservation and restorations for the fishery of the UVN including the *M.kannume* the bait targeted fish.

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APPENDICES

APPENDIX 1: PUBLISHED PAPERS

Paper 1: Abstract-1: Effects of exploitation pressures and river damming on the population structure of Elephant snout fish (*Mormyrus kannume*) Forsskal 1775: A case study on the upper Victoria Nile, East Africa.**S. Bassa[1*], D.O. Owiti[1a], A. Getabu[1b], H. Nakiyende[1], J.S. Balirwa[1], W. Nkalubo[1], J.V. Natugonza[1], D. Mbabazi[1] and A.M. Taabu[1]**

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Abstract

The Elephant snout fish (*Mormyrus kannume*) Forsskal (1775) is one of the riverine fish species that was previously important for the River Nile riparian people as food and income. The fish is currently, exploited mainly as bait for the Nile perch. This study was, conducted from 2008 to 2016 and focused on catch rates, value, size structure, maturity status, and feeding habits of *M. kannume*. Annual catch estimates were, made in order to evaluate the exploitation rate of the fish. Results revealed clear fluctuations in catches with a general increase in revenue from 1,200 (000) US$ to 8,600 (000) US$. With comparison to available literature, the fish exhibited a smaller size at maturity and smaller mean focal length (L_{50} for males and females were 25.2 and 28.2 cm; mean fork length of (25.9±0.32 cm). The observed changes could be due to increased fishing effort along with gear changes from gillnets to basket traps. Therefore, the exploitation rate of the Elephant snout fish in the upper Victoria Nile may be unsustainable

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APPENDIX 2: PAPER 2:Abstract-2: Assessment of the Ecosystem integrity of the Upper Victoria Nile (UVN), East Africa based on Habitat and Fish species biotic indices.**S. Bassa[1*], A. Getabu[3],D.O.Owiti[2],A.M.Taabu[4],E.Ogello[2],N.E.Orina[3],L.,I,.Muhoozi[1], R.Olwa[1], H. Nakiyende[1], D.Mbabazi[1], E.K.Muhumuza[1],J.S.Balirwa[1] and W. Nkalubo[1].**

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Abstract

Riverine ecosystems are continuously been compromised by human activities resulting in threatening their integrity. In this study, integrity of Upper Victoria Nile River was, assessed using habitat quality and fish biotic indices. Experimental gillnetting was done bi-annually in 9 stations along the river from 2008 to 2018. Nine habitat metrics were, used to estimate habitat quality index at every sampling station. Fish were sampled, sorted and identified to species level, and weighed. Counts of introduced and indigenous as well as tolerant and intolerant species were, recorded to generate species richness. Ten thousand six hundred forty two (10,642) fishes, 65 species belonging to nine families were, recorded. Dominant species were *Lates niloticus* 62.79%, *Oreochromis niloticus* 23.51%, *and Mormyrus kannume* 13.64%; other species were ≤0.06%. Tolerance and trophic guild showed carnivores (61.5%), omnivores (21.5%) and detrivores (16.9%). Mean habitat quality index, total fish catch and fish-based index of biotic integrity varied among stations with highest record of 26.6±6.9, 289.2±51.8 and 30.6±7.9 at sampling station (ST4) respectively. The lowest was 19.4±7.3, 93.1±13.2 and 26.7±6.8 at sampling station (ST2) respectively. On a spatial basis, indices recorded significant differences among stations ($p < 0.05$). Results indicated a fair fisheries biodiversity that need better conservation management of habitat type of the upper Nile.

APPENDIX 3: PAPER 3:Abstract-3: Stock assessment of *Lates niloticus* (Linnaeus 1758) Upper Victoria Nile, Bujagali area, East Africa, and its impact on National economy.**S.Bassa [1*], A.Getabu[3], E.O. Ogello[2], A.M.Taabu[4], D.O.Owiti[2], H.Nakiyende[1], J.S.Balirwa[1], J.K.Nyaundi[5], L.Musinguzi[1,] and W.Nkalubo[1]**

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Abstract

This study investigated growth, mortality, recruitment and catch estimates of Nile perch, *Lates niloticus* (Linnaeus, 1758)in Upper Victoria Nile, based on total catches and length-frequency data collected during the period 2008-2018. The asymptotic length (L_∞) had a value of 93.45 cm TL, growth curvature (K) of 0.446 year^{-1}, total mortality (Z) of 1.85year^{-1}, natural mortality (M) of 0.79 year^{-1}, fishing mortality (F) of 1.09 year^{-1}, exploitation rate (E) of 0.59 and growth performance index ($\varnothing$) of (L_∞) was 3.604. There were two peaks recruitment period, a minor in March and a major in August, accounting for 12.8% and 26.3% respectively, of the total fish catch. Beverton and Holt's relative yield-per-recruit model indicted indices for sustainable yield were 0.278 for optimum sustainable yield ($E_{0.5}$), 0.421 for maximum sustainable yield (E_{max}) and 0.355 for economic yield ($E_{0.1}$). Comparing with the previous findings from other systems lakes Kyoga and Victoria, there is a high decline in the population sizes of *Lates niloticus* in Upper Nile. Therefore, this requires strict management of the fishery thus adherence to the slot size of 50-85 cm TL. Then barn of illegal fishing gears; thus enforcement and fisheries monitoring, control and surveillance for sustainability of the Nile perch fishery need to be adhered too since there is ecosystem overfishing.

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APPENDIX 4: PAPERS SUBMITTED IN THE JOURNAL, UNDER REVIEW:

Paper 1:Abstract-1: Saving the endangered Native Tilapiines, *Oreochromis variabilis* Boulenger (1906) in Upper Victoria Nile, East Africa

Samuel Bassa[1*], Dickson Otieno Owiti[2], Erick. Ogello[2], Albert Getabu[3], Hebert Nakiyende[1], Winnie Nalukenge Nkalubo[1], Mark Olokotum[1], Stephen Sekiranda[1], Laban Musinguzi[1], John Balirwa[1], Joseph Nyaunde[4] and Anthony Munyaho Taabu[1].

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Abstract

The native Victoria tilapiines, *Oreochromis variabilis* Boulenger (1906) is critically, endangered in the upper Victoria Nile and the Lake Victoria basin. This study investigated the population characteristics of the native tilapiines in the upper Victoria Nile for ten years, (i.e. 2008 to 2018). Catch estimates, mortality, growth, food and feeding habits and water parameters evaluated. The catch rates ranged 0.32±0.08 to 3.42±1.13 kg, boat^{-1}, day^{-1}.The parameters of fish length-weight relationship were calculated from the aggregated data as $W=0.000031L^{3.126}$ (R^2=0.9119), indicating Isometric growth between the relationship. The length frequency samples were analysed using FISAT II software, including ELEFAN-I method. The growth parameters obtained using ELEFAN I was: L_∞=36.75, K=0.44 yr^{-1}, t_0=-0.4540, t_{max}=6.4years, ØL=2.774, ØW=-0.301.Estimation of the mortality parameters of Z=1.74yr^{-1} estimated. The value of natural mortality (M) was calculated as M=0.95yr^{-1}using riverine surface temperature of (RST) 26^{o}C.Thus the fishing mortality F was 0.79 yr^{-1} and exploitation ratio (E) was 0.4504. The growth parameters concurs with the annual estimates and yield recorded. ANOVAs test subjected to the *O.variabilis* indicted (F=6.589; P<0.05) in terms of length yet in terms of catch rates kg^{-1}boat^{-1}day^{-1}.Gut contents recorded significant difference the same applied to the water parameters. The catch estimates correlated with water parameters that indicated a significant difference. Mortality parameters indicated that the fishery could be experiencing excessive exploitation pressure, though, growth rates revealed that *O. variabilis* is a long-lived species and once managed properly, its population could recover**. (*Submitted to the Uganda journal of Agricultural sciences under review).***

APPENDIX 5: PAPERS STILL IN PRINT: Abstract-5: Vulnerability of fisheries – depended communities to river damming: A case of Bujagali Hydropower Dam on upper Victoria Nile (UVN), Uganda.Nduwayesu Everest, Basooma Anthony, Balirwa John Stephen, Sekiranda Stephen, Bassa Samuel, Musobya Moses, Mangeni Sande-Richard, Muhumuza Elias, Nkalubo Winnie, Mageni Bairon and Nakiyende Hebert

Abstract:

The upper Victoria Nile (UVN) a reach of Nile River interconnects lakes Victoria and Kyoga supporting a diverse aquatic fauna that sustains livehood of dependent communities through fishing. The UVN is home for a rare Neochromis semotes and refugia for the endangered *Oreochromis variabilis*, *O.esculentus* and *Labeo victorianus*.Along the UVN provides renewable energy to spur Uganda's industrial and socio-economic developments. This paper provides information on fishing effort, species abundance and catches composition, species unit price, gross values of production from 2009 to 2019.Monitoring was conducted bi-annually during April and September at three transects; upstream (Kirinya-Makwanzi), Reservoir and downstream of Buyala-Kikubamutwe. Fishing boats increased from31 to 293, fishers from83 to 500. Annual fish catches recorded variations in catch estimates thus the lowest observed in 2017 (156.88±5.44) and highest in 2019 (1,072.41±164.46). Species such as *Protopterus aethiopicus* and *Labeo victorianus* were a bit scarce during the whole monitoring survey. A new bait fishery for *Mormyrus kannume* emerged. Therefore, this fishery needs proper management for production and sustainability.

(Still under review)

APPENDIX 6.BIOMETRIC DATA SHEET

FORM B Biometric Data Sheet for fish Studies Sheet No_________

Species___________ Lake_______ Catch (Com) (Exp) Station__________ Date __________ Season (D) (W)

Serial No	Site	Time (D) (N)	Geart type	Gear size	TL/FL(cm)	SL(cm)	Wt(g)	Fat Cont.	Sex	Gon.State	Gon Wt (g)	Stom.Full	Wt.Food (g)	Prey 1	Dig state	% Wt	Length (cm)	Prey 2	Dig state	% Wt	Length (cm)	Parasite	

APPENDIX 7.CATCH DATA SHEET

FORM A Catch Compostion Data Sheet Sheet No________

Dates__________ Lake______ Station_________ Latitude _________ Longtitude_____________ Habitat__________

Site	Depth (m)	Geart type	Operation Act/Pas	Mesh Size	Number	Species/Taxa	No. of fish	Tot. of Wt (g)	Total/Fork Length of individual speciemens (cm)

APPENDIX 8 CATCH ASSESSMENT DATA SHEET

Part A Document identification

Date	
Country	
District	
Sub-county/Division	
Parish/Location	
Landing site Name/Code	
Enumerators name	

Part B – Vessels landing and Sampling targets

Number of vessels (all types) that landed at the site during the sampling day (00:00 to 24:00 hrs)	=	
Maximum number of vessels that can be sampled	=	
Sampling proportion	=	

Number of Vessels landing during the sampling day (00:00 – 24:00hrs)

	Main gear type			
Vessel type	**SN**	**GN**	**LL**	**Other**
Parachute				
Sesse (Motorised/Sail)				
Sesse (Paddled)				
Other				

Number of Vessels to be sampled

	Main gear type			
Vessel type	**SN**	**GN**	**LL**	**Other**
Parachute				
Sesse (Motorised/Sail)				
Sesse (Paddled)				
Other				

Form Codes for Part C

Vessel type Code	**Description**
SMS	Sesse Motorised or sail
SP	Sesse paddled
PA	Parachute

Gillnet panel code	**Description**
S	Single
D	Double
T	Triple

OT	Other
Propulsion code	
O	Outboard motor
P	Paddles
S	Sail
Gear type code	
GN	Gillnet
LL	Long line
SN	Seine net
SN	Scoop net
HL	Hand line
LN	Lift net
CN	Cast net
TR	Trap
OT	Other

Mode of operation	
A	Active
D	Drift
S	Stationary
Construction	
MO	Monofilament
MU	Multifilament
Fish species code	
NP	Nile perch
TL	Tilapia
DA	Dagaa/Mukene
HA	Haplochromines (Furu/Nkejje)
BD	Bagrus docmac
PA	Protopterus aethiopicus
CG	Clarias gariepinus
OT	Other

Part C – Fishing Operations

Form Number		District	
Date		Landing site Name or Code	
Country		Enumerator’s Name	

Use separate rows for each gear size and species. Ensure that hours fished with each gear type is recorded

VESSEL DETAILS							GEAR AND EFFORT DETAILS								FISH CATCH DETAILS				
Serial Number	**Reg. No.**	**Vessel type code**	**Length (m)**	**Propulsion code**	**Crew**	**Days fished in the last one week**	**Gear type code**	**Construction code**	**GN panel code**	**Number of units**	**Size GN mesh (inches) SS mesh (mm) or Hook size No.**	**Mode of operation Code**	**Hours fished**	**Number of lamps (Dagaa)**	**Species name or Code**	**No. of fish (large spp) No. basins/buckets (Dagaa/Mukene and Nkejje/Furu)**	**Catch wt (kg) large spp Wt (kg) 1 basin/ bucket (Dagaa/Mukene & Nkejje/Furu)**	**Price (shs/kg) large spp Price 1 basin/bucket Dagaa& Nkejje**	**Domestic consumption (kg)**

APPENDIX 9: PRINCIPAL COMPONENT ANALYSIS

PERMANOVA									
Permutational	MANOVA								
Resemblance	worksheet								
Name:	Resem1								
Data	type:	Distance							
Selection:	All								
Normalise									
Resemblance:	D1	Euclidean	distance						
Sums	of	squares	type:	Type	III	(partial)			
Fixed	effects	sum	to	zero	for	mixed	terms		
Permutation	method:	Permutation	of	residuals	under	a	reduced	model	
Number	of	permutations:	999						
Name	Abbrev.	Type	Levels						
Year	Ye	Fixed	12						
Site	Si	Fixed	3						

PERMANOVA	table	of	results			
	Unique					
Source	df	SS	MS	Pseudo-F	P(perm)	perms
Ye	11	350.72	31.883	2.5998	0.001	996
Si	2	23.941	11.971	0.97608	0.459	999
YexSi**	18	103.57	5.7538	0.46916	1	997
Res	29	355.65	12.264			
Total	60	840				
**	Term	has	one	or	more	empty cells

Details	of	the	expected	mean	squares	(EMS)	for	the	model
	EMS								
Source									
Ye	1*V(Res)	+	4.9756*S(Ye)						
Si	1*V(Res)	+	18.462*S(Si)						
YexSi	1*V(Res)	+	1.9059*S(YexSi)						
Res	1*V(Res)								
Construction	of	Pseudo-F	ratio(s)	from	mean	squares			
Source	Numerator	Denominator	Num.df	Den.df					
Ye	1*Ye	1*Res	11	29					
Si	1*Si	1*Res	2	29					
YexSi	1*YexSi	1*Res	18	29					
Estimates	of	components	of	variation					
Source	Estimate	Sq.root							
S(Ye)	3.9431	1.9857							
S(Si)	-0.015889	-0.12605							
S(YexSi)	-3.4157	-1.8482							
V(Res)	12.264	3.502							

APPENDIX 10: ANOVA FOR THE ECOSYSTEM PARAMETERS (P<0.05) SAMPLED FROM 2014-2019 UPPER VICTORIA NILE.

			Sum of Squares	df	Mean Square	F	Sig.
SD (m) * Year	Between Groups	(Combined)	7.903	5	1.581	12.942	.000
		Linearity	.180	1	.180	1.473	.232
		Deviation from Linearity	7.723	4	1.931	15.809	.000
	Within Groups		4.641	38	.122		
	Total		12.544	43			
DO (mg/L) * Year	Between Groups	(Combined)	14.168	5	2.834	14.962	.000
		Linearity	2.630	1	2.630	13.886	.001
		Deviation from Linearity	11.538	4	2.885	15.231	.000
	Within Groups		7.197	38	.189		
	Total		21.364	43			
T °C * Year	Between Groups	(Combined)	16.723	5	3.345	3.316	.014
		Linearity	1.757	1	1.757	1.742	.195
		Deviation from Linearity	14.965	4	3.741	3.709	.012
	Within Groups		38.329	38	1.009		
	Total		55.052	43			
pH * Year	Between Groups	(Combined)	6.259	5	1.252	11.371	.000
		Linearity	2.219	1	2.219	20.155	.000
		Deviation from Linearity	4.040	4	1.010	9.174	.000
	Within Groups		4.183	38	.110		
	Total		10.442	43			
Cond. (µScm-1) * Year	Between Groups	(Combined)	133.077	5	26.615	4.811	.002
		Linearity	.259	1	.259	.047	.830
		Deviation from Linearity	132.818	4	33.205	6.002	.001
	Within Groups		210.230	38	5.532		
	Total		343.308	43			
NH4-N (ug/L) * Year	Between Groups	(Combined)	14579.824	5	2915.965	113.089	.000
		Linearity	5393.631	1	5393.631	209.180	.000

		Deviation from Linearity	9186.194	4	2296.548	89.067	.000
	Within Groups		979.814	38	25.785		
	Total		15559.639	43			
NO2-N (µg/L) * Year	Between Groups	(Combined)	672.091	5	134.418	4.301	.003
		Linearity	335.074	1	335.074	10.720	.002
		Deviation from Linearity	337.017	4	84.254	2.696	.045
	Within Groups		1187.733	38	31.256		
	Total		1859.824	43			
NO3-N (µg/L) * Year	Between Groups	(Combined)	12507.881	5	2501.576	1.164	.345
		Linearity	1642.641	1	1642.641	.764	.388
		Deviation from Linearity	10865.240	4	2716.310	1.263	.301
	Within Groups		81700.855	38	2150.023		
	Total		94208.736	43			
PO4-P (µg/L) * Year	Between Groups	(Combined)	36.620	5	7.324	.449	.812
		Linearity	1.907	1	1.907	.117	.734
		Deviation from Linearity	34.713	4	8.678	.532	.713
	Within Groups		620.319	38	16.324		
	Total		656.939	43			
TP (µg/L) * Year	Between Groups	(Combined)	22885.559	5	4577.112	2.750	.032
		Linearity	1686.940	1	1686.940	1.013	.320
		Deviation from Linearity	21198.619	4	5299.655	3.184	.024
	Within Groups		63251.631	38	1664.517		
	Total		86137.190	43			
TN (µg/L) * Year	Between Groups	(Combined)	3056506.855	5	611301.371	2.747	.033
		Linearity	2235143.864	1	2235143.864	10.043	.003
		Deviation from Linearity	821362.991	4	205340.748	.923	.461
	Within Groups		8457572.836	38	222567.706		
	Total		11514079.692	43			
SRSi (µg/L) * Year	Between Groups	(Combined)	72621.982	5	14524.396	.841	.529
		Linearity	70339.190	1	70339.190	4.072	.051

		Deviation from Linearity	2282.792	4	570.698	.033	.998
	Within Groups		656448.810	38	17274.969		
	Total		729070.792	43			
TSS (mg/L) * Year	Between Groups	(Combined)	2.595	5	.519	.638	.672
		Linearity	.937	1	.937	1.153	.290
		Deviation from Linearity	1.658	4	.414	.510	.729
	Within Groups		30.895	38	.813		
	Total		33.490	43			
sum HQI * Year	Between Groups	(Combined)	241.653	5	48.331	3.853	.006
		Linearity	23.299	1	23.299	1.857	.181
		Deviation from Linearity	218.354	4	54.588	4.352	.005
	Within Groups		476.693	38	12.545		
	Total		718.345	43			
RICHNESS * Year	Between Groups	(Combined)	1632.676	5	326.535	74.695	.000
		Linearity	118.286	1	118.286	27.058	.000
		Deviation from Linearity	1514.391	4	378.598	86.605	.000
	Within Groups		166.119	38	4.372		
	Total		1798.795	43			
Simpson * Year	Between Groups	(Combined)	826.859	5	165.372	1.061	.397
		Linearity	112.409	1	112.409	.721	.401
		Deviation from Linearity	714.449	4	178.612	1.146	.350
	Within Groups		5923.939	38	155.893		
	Total		6750.797	43			
Shannon * Year	Between Groups	(Combined)	.097	5	.019	1.499	.213
		Linearity	.052	1	.052	4.001	.053
		Deviation from Linearity	.045	4	.011	.874	.488
	Within Groups		.491	38	.013		
	Total		.588	43			
evenness * Year	Between Groups	(Combined)	.051	5	.010	6.315	.000
		Linearity	.004	1	.004	2.722	.107

		Deviation from Linearity	.046	4	.012	7.213	.000
	Within Groups		.061	38	.002		
	Total		.112	43			
FIBI * Year	Between Groups	(Combined)	534.220	5	106.844	44.927	.000
		Linearity	426.842	1	426.842	179.481	.000
		Deviation from Linearity	107.379	4	26.845	11.288	.000
	Within Groups		90.371	38	2.378		
	Total		624.592	43			
Abundance * Year	Between Groups	(Combined)	7079397.050	5	1415879.410	54.878	.000
		Linearity	681658.891	1	681658.891	26.420	.000
		Deviation from Linearity	6397738.159	4	1599434.540	61.992	.000
	Within Groups		980420.458	38	25800.538		
	Total		8059817.508	43			

APPENDIX 11: ANOVA FOR THE ECOSYSTEM PARAMETERS (P<0.05) SAMPLED SITES UVN

			Sum of Squares	df	Mean Square	F	Sig.
SD (m) * Site	Between Groups	(Combined)	2.622	8	.328	1.597	.135
	Within Groups		20.321	99	.205		
	Total		22.943	107			
DO (mg/L) * Site	Between Groups	(Combined)	9.929	8	1.241	2.039	.049
	Within Groups		60.268	99	.609		
	Total		70.197	107			
T °C * Site	Between Groups	(Combined)	4.079	8	.510	.725	.669
	Within Groups		69.635	99	.703		
	Total		73.714	107			
pH * Site	Between Groups	(Combined)	1.197	8	.150	.780	.621
	Within Groups		18.991	99	.192		
	Total		20.188	107			
Cond. (µScm-1) * Site	Between Groups	(Combined)	1418.394	8	177.299	3.512	.001
	Within Groups		4997.878	99	50.484		
	Total		6416.272	107			
NH4-N (ug/L) * Site	Between Groups	(Combined)	2792.247	8	349.031	.884	.533
	Within Groups		39109.959	99	395.050		
	Total		41902.205	107			

NO2-N (µg/L) * Site	Between Groups	(Combined)	68.205	8	8.526	.621	.758
	Within Groups		1358.871	99	13.726		
	Total		1427.076	107			
NO3-N (µg/L) * Site	Between Groups	(Combined)	66137.852	8	8267.231	4.513	.000
	Within Groups		181359.289	99	1831.912		
	Total		247497.141	107			
PO4-P (µg/L) * Site	Between Groups	(Combined)	182.156	8	22.769	1.061	.396
	Within Groups		2124.039	99	21.455		
	Total		2306.195	107			
TP (µg/L) * Site	Between Groups	(Combined)	10899.580	8	1362.447	1.248	.280
	Within Groups		108103.169	99	1091.951		
	Total		119002.749	107			
TN (µg/L) * Site	Between Groups	(Combined)	18062972.965	8	2257871.621	4.430	.000
	Within Groups		50455804.562	99	509654.592		
	Total		68518777.527	107			
SRSi (µg/L) * Site	Between Groups	(Combined)	956788.261	8	119598.533	6.873	.000
	Within Groups		1722835.885	99	17402.383		
	Total		2679624.146	107			
TSS (mg/L) * Site	Between Groups	(Combined)	17.134	8	2.142	3.326	.002
	Within Groups		63.760	99	.644		
	Total		80.894	107			
sum HQI * Site	Between Groups	(Combined)	414.014	8	51.752	3.988	.000
	Within Groups		1284.754	99	12.977		

	Total		1698.769	107			
RICHNESS * Site	Between Groups	(Combined)	8614.098	8	1076.762	73.002	.000
	Within Groups		1460.226	99	14.750		
	Total		10074.324	107			
Simpson * Site	Between Groups	(Combined)	.230	8	.029	14.256	.000
	Within Groups		.199	99	.002		
	Total		.429	107			
Shannon * Site	Between Groups	(Combined)	4.824	8	.603	10.353	.000
	Within Groups		5.766	99	.058		
	Total		10.591	107			
evenness * Site	Between Groups	(Combined)	.275	8	.034	15.818	.000
	Within Groups		.215	99	.002		
	Total		.490	107			
FIBI * Site	Between Groups	(Combined)	235.870	8	29.484	8.502	.000
	Within Groups		343.315	99	3.468		
	Total		579.185	107			
abundance * Site	Between Groups	(Combined)	1758432.162	8	219804.020	4.473	.000
	Within Groups		4864753.962	99	49138.929		
	Total		6623186.124	107			

APPENDIX 12: ANOVA FOR THE ECOSYSTEM PARAMETERS SAMPLED SITES UVN USING PCA (THE TEMPORAL PATTERN OF THE PARAMETERS)

```
Response: BasaLim[, i]
Df  Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2  0.2696 0.13479  0.7299 0.4863
Residuals    58 10.7112 0.18468
Analysis of Variance Table

Response: BasaLim[, i]
Df  Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2   2.467  1.2334   0.538 0.5868
Residuals    58 132.973  2.2926
Analysis of Variance Table

Response: BasaLim[, i]
             Df Sum Sq Mean Sq F value   Pr(>F)
BasaLim$Site  2  9.163  4.5815  5.8416 0.004883 **
Residuals    58 45.489  0.7843
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Analysis of Variance Table

Response: BasaLim[, i]
Df  Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2  0.2665 0.13324  0.5012 0.6084
Residuals    58 15.4194 0.26585
Analysis of Variance Table

Response: BasaLim[, i]
             Df Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2  1.919 0.95941  1.6181 0.2071
Residuals    58 34.389 0.59291
Analysis of Variance Table

Response: BasaLim[, i]
             Df Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2   37.6  18.791  0.3335 0.7178
Residuals    58 3267.7  56.340
Analysis of Variance Table

Response: BasaLim[, i]
Df  Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2   31551   15776  0.1585 0.8538
```

```
Residuals    58 5772936   99533
Analysis of Variance Table

Response: BasaLim[, i]
             Df Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2   4137  2068.7  1.4129 0.2517
Residuals    58  84921  1464.2
Analysis of Variance Table

Response: BasaLim[, i]
Df  Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2   18.86   9.431  0.2534  0.777
Residuals    58 2158.96  37.223
Analysis of Variance Table

Response: BasaLim[, i]
             Df Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2  14001  7000.3  1.2144 0.3043
Residuals    58 334338  5764.5
Analysis of Variance Table

Response: BasaLim[, i]
             Df   Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2  1558789  779394    0.55 0.5799
Residuals    58 82184295 1416971
Analysis of Variance Table

Response: BasaLim[, i]
             Df Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2   94.4  47.194  0.4039 0.6695
Residuals    58 6776.4 116.834
Analysis of Variance Table

Response: BasaLim[, i]
             Df Sum Sq Mean Sq F value Pr(>F)
BasaLim$Site  2   3317  1658.7  0.4581 0.6348
Residuals    58 210022  3621.1
Analysis of Variance Table

Response: BasaLim[, i]
             Df     Sum Sq  Mean Sq F value Pr(>F)
BasaLim$Site  2   29516902 14758451  0.4334 0.6504
Residuals    58 1974851848 34049170
```

APPENDIX 13: ANOVA FOR THE ECOSYSTEM PARAMETERS SAMPLED SITES UVN USING PCA (TUKEY TEST FOR SPATIAL)

```
>basaov<- aov(BasaLim$DO~BasaLim$Site, data = BasaLim)
>summary(basaov, type=III)
             Df Sum Sq Mean Sq F value  Pr(>F)
BasaLim$Site  2   9.16   4.582   5.842 0.00488 **
Residuals    58  45.49   0.784
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>TukeyHSD(basaov)
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = BasaLim$DO ~ BasaLim$Site, data = BasaLim)

$`BasaLim$Site`
                          diff        lwr         upr     p adj
Midstream-Downstream -0.7234783 -1.4304339 -0.01652258 0.0437714
Upstream-Downstream  -0.8404348 -1.4685814 -0.21228817 0.0059024
Upstream-Midstream   -0.1169565 -0.8239122  0.58999916 0.9165490
```

APPENDIX 14: PCA-OUTPUTS

PCA									
Principal	Component	Analysis							
Data	worksheet								
Name:	NormalizedData								
Data	type:	Environmental							
Sample	selection:	All							
Variable	selection:	All							
Eigenvalues									
PC	Eigenvalues	%Variation	Cum.%Variation						
	1	2.88	20.6	20.6					
	2	2.04	14.5	35.1					
	3	1.69	12	47.1					
	4	1.58	11.3	58.4					
	5	1.12	8	66.4					
Eigenvectors									
(Coefficients	In	the	linear	combinations	of	variables	making	up	PC's)
Variable	PC1	PC2	PC3	PC4	PC5				
Secchi	-0.341	0.046	-0.35	0.17	-0.236				
TSS	0.057	-0.304	0.032	-0.443	0.258				
DO	-0.068	-0.291	0.133	0.572	0.033				
PH	-0.017	0.428	-0.263	0.024	0.442				
Temp	0.312	0.303	0.201	0.24	0.064				
Cond.	0.113	0.134	0.257	-0.226	-0.454				
SRSi	0.005	-0.518	0.107	-0.198	0.317				
NH4-N	0.033	-0.381	-0.444	0.164	-0.361				
NO2-N	0.48	0.127	-0.012	-0.002	-0.089				
NO3-N	0.384	-0.246	-0.272	0.125	0.21				
TN	-0.173	-0.113	0.397	0.352	-0.039				
SRP	-0.221	0.091	-0.354	-0.25	-0.171				
TP	-0.246	0.129	-0.192	0.211	0.392				
NP_Ratio	0.498	-0.016	-0.284	0.16	-0.06				